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REGIONAL SYMPOSIUM ON WATER USE AND CONSERVATION

28 November - 2 December 1993
Amman - Jordan

INTEGRATION OF WATER HARVESTING IN AGRICULTURAL PRODUCTION SYSTEM

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Organized by the
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DEFINITION AND CHARACTERISTICS OF ARID & SEMI-ARID REGIONS

Arid regions are defined by most authors as areas where potential evapotranspiration is much greater than precipitation. Although climatic boundaries are not well defined, arid regions can be sub-divided into arid and semi-arid zones, corresponding, according to Meigs (1953), to "deserts" and "steppe". Different classifications were given later by different authors based on different criteria such as temperature aridity, moisture, potential evapotranspiration, precipitation, altitude and the length of growing season. UNESCO and FAO, in 1977 published a map of arid zones in the world based on aridity indices, soil, vegetation, field observation, length of the dry period, and the rainfall pattern (table 1). A more complete approach in terms of potentiality for crop production was provided by FAO's agro-ecological zonation (Kotschi et al., 1986).

Table (1): (Sub) Climatic Zonation of the Arid and Semi-Arid

Regions According to UNESCO (1977)

Zonation	Hyper-arid	Arid	Semi-arid	Semi-humid
Annual Precipitation	nearly zero	80-150 (winter rain) 200-350 (summer rain)	200-500 (winter rain) 300-800 (summer rain)	more than 500-800
Interannual variability	up to 100%	50-100%	25-50%	less than 25%
Ratio P/ETP	less than 0.03	0.03-0.2	0.2-0.5	0.5-0.75
Vegetation	nearly absent	scattered	disconti-nuous steppe	steppe/savanna
potential land use	no rainfed agriculture, no grazing	nomadic livestock, AGRICULTURE ONLY THROUGH WATER HARVESTING	sedentary livestock and rainfed agriculture	livestock and agriculture

World Bank Technical Paper Number 91, 1988.

The most common features of Arid Lands may be summerized as follows:

* An eratic and unpredictable rainfall with great seasonal and annual fluctuations around the mean, as well as large geographic variations.

* A mean annual potential evapotranspiration much higher than the mean annual precipitation.

* Water is the most limiting factor for agricultural growth and production in arid and semi-arid regions.

* Large variations in space and time of temperature, rainfall patterns, and the degree of aridity.

In respect to the agricultural production system, arid and semi-arid lands are characterized by the following features.

- Low infiltration of rain water into the soil due to the erratic nature of rainfall and the relatively low soil permeability, giving rise to low soil moisture availability for plant growth, and low rate of recharge to groundwater aquifers.

- Low soil fertility and low content of organic matter in the soil.

- Mostly high soil salinity and some times high alkaliaity which adversely affect plant growth.

- Immature soil profiles.

- High soil erodibility.

- Poor vegetal cover, poor grazing lands and lack of forests, which all affect rainwater infiltration and runoff characteristics.

- Consequently low carrying capacity for rangeland to support animal production.

- Low plant productivity being limited by water and nutrients availability.

- Very fragile environmental system and high readiness for degradation of soil and vegetation (desertification) as a result of man interference.

WATER HARVESTING AND AGRICULTURE

Water harvesting iS the concentration, collection and storage of rain water and rainfall runoff, including soil storage, groundwater storage or surface ponding. Therefore, rainfall and runoff characteristics are the most controlling factors for the feasibility of water harvesting projects. Other important factors include:

- Topographic factors (land slopes).

- Vegetal cover as it affects rain water infiltration, surface runoff and soil erosion.

- Geologic formations exposed on the catchment surface.

- Soil cover including: extent, thickest, stratification, permeability and infiltration rate, and the moisture holding capacity of the soil. Theoretically water harvesting is feasible where ever surface runoff from rainfall or fog can be collected. However, it is of most interest in arid and semi arid regions where agricultural production is limited primarily by meager and eratic rainfall.

Water harvesting would be beneficial in the following cases:

* To supplement existing and limited irrigation water sources such as springs and wells.

* To counter act the low reliability and high variability of rainfall for rained agriculture in arid and semi-arid regions.

* To meet the increasing demand on agricultural food products, and the increased pressure on existing cultivated land and water resources.

* To increasing the production and productivity of existing rain-fed agriculture.

* To make more efficient use of the available unused agricultural resources, soil and water.

With regard to rainfall requirements for water harvesting, Pacey and Cullis (1986) set a minimum average annual rainfall of 100 mm for winter rainfall, and 150 mm for summer rainfall. The smaller the catchment areas the higher the rainfall requirement for water harvesting. However, other rainfall characteristics of storms are more important than the total annuals. These characteristics includes:

- Intensity, duration and frequency of individual rainfall events.

- Durations of drought periods between rainfall events.

- The initial abstraction losses of the catchment area which needs to be satisfied before surface runoff starts. Good hydrologic analysis is needed to determine these initial losses, and the time when surface runoff starts.

The soil requirements for the cultivated area in a water harvesting system are the same as those for the irrigated agriculture.

Based on the available soil, water, topographic and climatic conditions, zonation of the region can be made for the potential areas were water harvesting would be viable.

In addition to the soil and water requirements, there are also plant requirements which favor a specific water harvesting technique more than others, or which make a given plant species more fit for water harvesting than others. Examples are:

- Trees require concentration of harvested water at points, therefore, micro-catchments are most adequate.
- Cereals require uniform water distribution, and the water spreading is most favorable.
- Grass requires less uniform distribution, and it has a low value, therefore low-cost spreading techniques are suitable.
- Plants which withstand draught and temporary water logging are recomended for water harvesting systems.
- Plants with low sensitivity to low fertility are also adequate.
- Plants with short growing season and fast maturity are most favorable for water harvesting.
- Plants with higher degree of positive response to water availability are most adequate.

THE NEED FOR INTEGRATED MANAGEMENT OF WATER HARVESTING AND THE AGRICULTURAL PRODUCTION SYSTEMS

The world's irrigation in the closing decade of the 20th century is characterized by low performance, increased demand for higher agricultural productivity, decreased availability of water for irrigation, potential uncertainties resulting from global climatic change, and a changing role of the public sector.

In most countries around the world. Significantly more water is delivered per unit area than is required.

In addition, increases in areas affected by water logging and salinity, declining water tables and increasing groundwater salinity, raise worrying concerns about the sustainability of irrigation systems.

Meeting the challenge of increasing demand on agricultural production and productivity, and enhancement of income in the rural areas would be a significant strategy. Without agricultural growth, the rise in population will be far too large in relation to agricultural production.

The next decade will also be characterized by growing water scarcity and competetion on its use, which would result in declining the share of water available for agriculture, and in the investments in irrigation expansion.

This decrease in the water availability for agricultural purposes, coupled with the requirement for higher agricultural productivity, means that the world has no option but to improve the efficiency of water use for agriculture in order to achieve "more with less", and to efficiently develope rain water which would other wise evaporates or discharges into the sea.

To address these challenges, it is also required to integrate planning and management for agriculture and water of which water harvesting is one of the practices for their management.

PROSPECTS FOR IMPROVEMENTS IN THE AGRICULTURAL PRODUCTION SYSTEM, THROUGH WATER HARVESTING:

Water harvesting is believed to be an important tool to improve water yields and significantly increase plant and animal production in arid and semi-arid regions. It is one of many water management practices by means of which water availability to plants can be improved.

Water in many areas is the limiting factor for expansion of agricultural development. Large areas of available land could be cultivated if water is made available. In areas, were total annual rainfall is not sufficient for plant growth, water harvesting techniques could provide the additional water needed for plant growth and production, and thus making efficient use of rain water, and the unused arable land.

Irrigation water sources, such as springs and wells, in arid and semi-arid regions are subject to high seasonal and annual fluctuations, and some times are threatened by depletion due to over pumping of aquifers or reallocation, wholy or partly, for domestic water supplies. Under such conditions water harvesting could compensate for some of the water shortages as a supplementary irrigation water source.

Increasing plant production by water harvesting can be achieved for crops, fruit trees, forests and fodder.

Rain water harvesting should be looked at as a mechanism for survival in arid and semi-arid regions. Under water harvesting systems the land is managed for the maximum water output for plant growth. Water harvesting allows the combined use not only for farming, but also for a better reception and delivery of rain water as a harvest of fresh water.

<u>Integration of water harvesting in the agricultural production could achieve the following benefits:</u>

* Increase of plant growth and production for crops, fruit trees, grasses, range land, and forests. On the long run, however, the addition of nutrients may be needed.
  Some authors reported that nutrient harvesting also occurs with water harvesting from the catchment area. The availability of nutrients is necessary to sustain crop yields.

* The production of grass and fodder crops can be improved by water harvesting. Planned management and fencing for production of grazing land is necessary.

* Such enhancement of range land and provision of drinking water can result in increasing animal production.

* Erosion control of soil is always an integral part, and a primary objective of water resources management of which water harvesting is one aspect.

* On the other hand, some erosion of the catchment area is positive as the eroded soil deposits in the cultivated area, and it often contains nutrients leading to a renewal of soil fertility. It is necessary however to apply appropriate farming practices to achieve soil conservation.

* The increase of vegetal growth under water harvesting practices will lead to higher infiltration rates. Infiltrating water would be either stored in the soil or percolates deeper to recharge ground water aquifers.

* Water harvesting techniques coupled with appropriate farming practices would not only conserve soil and soil moisture, but they would also decrease the surface runoff reaching the downstream channels, and thus it would also help decrease flood damage.

The above mentioned improvements of the agricultural production system would give rise to improvements of the socio-economic aspects of the population in the rural areas, by increasing income and creating new job opportunities, and would thus decrease the out-migration from the rural to the urban areas.

THE MECHANISM THROUGH WHICH WATER HARVESTING CAN BE SUCCESSFULLY INTEGRATED INTO THE AGRICULTURAL PRODUCTION SYSTEM

Achievement of significant increase in agricultural production is no longer feasible through expansion of cultivated area in many countries, particularly through irrigation with existing water sources. However, agricultural productivity in the irrigated and rainfed areas can still be increased to a certain extent through rain-water harvesting.

Marginal lands with annual rainfall less than 250mm cannot support crop growth and production. Large areas under this category may be cultivated if additional water becomes available. Such incremental water supply can be provided through appropriate water harvesting techniques.

The high seasonal and annual variability of rainfall in arid and semi-arid regions are also reflected on the reliability of the agricultural production system.

Application of appropriate water harvesting techniques can increase both productivity and reliability.

Other water sources of irrigated agricultural in the arid and semi-arid regions, such as springs, streams' base flow, flood flows, and ground water wells are also subject to seasonal and longer term fluctuations in response to rainfall fluctuations.

They are also subject to depletion or quality deterioration due to over-development, or to other competitive uses such as domestic and industrial. Water harvesting may supplement the irrigation requirement under such variable conditions.

Improvements in the agricultural production system using water harvesting techniques depend on many factors, the following are the most important:

- Selection of appropriate sites for water harvesting (catchment and cultivated areas).
- Selection of appropriate water harvesting techniques which are also safe, simple and inexpensive.
- Selection of appropriate crops and plant species.
- Adoption of appropriate farming techniques.
- Provision of appropriate maintenance.
- Farmers understanding, awareness, appreciation and participation in the construction, operation, and maintenance of the water harvesting system.
- Availability of other cultivation requirements such as fertility, weeding, protection against pests, and services.
- The achievement of good hydrologic, soil, and land use data base is also essential to plan and design water harvesting systems.

The general public now understand that rainfall is highly variable in space and time. Its measurements can hot therefore be simple or cheap. It is therefore required that a pattern of raingages rather than a single gage be installed over a catchment area or a large cultivated area. Adequate funds are required to achieve good hydrologic information about rain, floods, reservoirs and groundwater. Such funds have been inadequately provided in the past, even in many technically advanced communities. Measurements obtained will be useful over a run of years so that future developments will benefit from today's measurements.

Designers of water and irrigation facilities must make sure that their facilities be successful. In the absence of information on rainfall and stream flow they have to design with costly increases of safety margins against unknown or uncertain risks.

Decisions on land use, the protection of water-sources areas, the allocation of resources to agricultural production and to the costly infrastructures to support it, all critically depend on estimates of the existing hydrological regimes. Therefore, improvement of national networks for collection of hydrological data should be one of the basic objectives of planning water resources and the agricultural production system.

Field surveys are also needed for the preparation of the needed maps such as:soil map, land-use map, land slope map, vegetation map, and hydrological maps.

Statistics on rainfed and irrigated agricultural production including livestock are also needed. Estimates for the potential for development of water resources and arable land as well as their constraints are also needed for development planning.

Socio-economic aspects should also be considered in water harvesting projects, such as: collective versus individual approach, public participation and incentives, maintenance issues and the role of women.

The sustainability of water harvesting programs is an essential issue. Such projects will be sustainable when the structures are maintained and replicated by the farmers themselves. Therefore, training of farmers in the techniques of water harvesting is essential. The community participation in the planning process and decision- making, and adoption of indigenous and low labor-input techniques are all important parameters to achieve sustainability of the projects.

Professional training of research and extension staff in relevant water harvesting techniques is also important, together with the provision of manuals on this subject.

Farmers' training is a precondition for sustained efforts in this sector. Training will enable farmers increase their knowledge and improve their skills. It should be aimed at the stimulation of farmers' and extension staff and may include:

- Annual training sessions on technical and practical aspects of water harvesting.
- On-farm trials and demonstration.
- On-form visits on the regional and inter-regional levels so that they can benefit from the experience of others.

The adoption of water harvesting techniques in the agricultural production system should be reflected in the national development policy. Such policy should aim at conservation of the natural resources (water and soil), rationalize their use, upgrade their productivity, promote research and development in the public and private sectors, and provide equitable distribution of economic activities between urban and rural areas.

The strategy for integrating water harvesting in the agricultural production system would be to achieve objectives such as:

1. Full utilization of under-utilized natural resources: soil and water.
2. Application of the principles:
   "more production for less water", and
   "proper crops growing in proper land".
3. Extention of appropriate harvesting techniques for effective utilization of water resources.
4. Balancing geographic distribution of socio-economic and environmental rehabilitation.
5. Alleviating out-migration from rural areas.
6. Up-grade indigenous technologies of water harvesting and cultivation of local crops and plants, as well as implementing anti-desertification technologies.

PROBLEMS AND CONSTRAINTS FOR AGRICULTURAL DEVELOPMENT USING WATER HARVESTING TECHNIQUES:

The following are the most significant problems and constraints which would face the intigration process of water harvesting in the agricultural production system.

1. Lack of adequate hydrological, soil and land use data base.

2. The use of generalized hydrologic techniques for estimating surface runoff from rainfall data and for deriving design criteria for the water harvesting structures. Some techniques are only valid under certain hydrologic and physiographic conditions.

3. Ignoring the indigenous water harvesting systems and experience and adoption of systems tested under different climatic, soil, and social conditions.

4. The wide gap between research and implementation, as well as the lack of actual field data on the increments of crop yields under different water harvesting systems.

5. Soil erosion in the cultivated areas resulting from poor farming practices and flash floods.

6. Potential soil moisture depletion by weeds and other natural vegetations in the cultivated areas.

7. Lack of technical advice, training, and other services and incentives to the farmers.

8. The lack of control on rain water availability both in time and space, because of the high variability and low reliability of rainfall in the arid and semi-arid regions.

9. Transferability of water harvesting techniques to other areas has never been explicitly a subject of research. The socio-economic and environmental conditions should be the key criteria for selection of the suitable technique.

10. Documentation and analysis of the existing indigenous water harvesting systems is still lacking in many countries.

11. The lack of risk analysis studies of crop failure due to the low reliability of rainfall in the arid and semi-arid areas.

12. The out-migration trends from rural to urban areas due to low income and lack of job opportunities in the rural areas.

13. Very little is known about maintenance requirements of different water harvesting systems. Maintenance should not be a burden on the labor capacity of rural households.

14. Land tenure is sometimes a problem for operating machineries.

15. Large-scale demonstration projects are still insufficient.

SUGGESTIONS AND PRIORITIES FOR IMPROVING CHANCES OF SUCCESS IN RESEARCH AND DEVELOPMENT PROJECTS:

1. Detailed hydrometeorlogical analysis of rainfall data (daily and storm by storm) is needed, including probability and risk analysis of intra-storms drought periods, rainfall intensities and durations of single rainfall events.

2. Analysis of the hydrological response of the main catchments to water harvesting and farming practices, particularly on the catchment water and sediment yields. The effect of the different water harvesting and farming techniques on soil erosion and soil and water conservation is needs to be evaluated.

3. There is a need for intensifying rainfall and surface runoff measurement networks to provide the data needed for projects planning and design. Small experimental water sheds, natural and artificial, would provide more realistic data on estimation of surface runoff from rainfall data, and would also provide significant input to mathematical and simulation prediction models.

4. The use of the Geographic Information System (GIS), would be most useful in identifying potential areas for water harvesting. Topographic, geologic, hydrologic, soil, vegetation, and land use maps would provide significant inputs for utilizing this technique.

5. There is a need to transfer water harvesting techniques from experimental stations to the field conditions on a large scale for more realistic demonstration and assessment of the increase of agricultural production in the real world.

6. Training of farmers, extension staff and close cooperation among them and the researchers and planners are all important factors in the success of projects. This includes community participation in all the project phases.

7. Several meetings conferences and workshops have already been arranged focussing on water harvesting, however, the spread of water harvesting is still limited, although the potential in many countries is high. Most of the obstacles are nontechnical.

8. The individual cultivators adopting such systems need to be economically rewarded for their efforts. Aid from international agencies should be directed to make such reward possible.

9. Consideration should be given to socio-economic aspects in project planning, implementation and maintenance such as: viability of indigenous systems and local experience, peoples priorities and participation, area differences, land tenure, subsidies and incentives, machinery and hard labor, the role of women, and monitoring and evaluation of results.

10. The combined use of land for agricultural and for reception and delivery of fresh water from rainfall is the right approach for managing land for maximum water output. Rain water harvesting could be a mechanism for survival in arid and semi-arid regions.

11. Continuing research in producing new and inexpensive sealing materials for land treatment to increase the water harvest from rainfall.