Water Harvesting techniques and strategies of soil and water conservation in Libya

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Abstract

Land degradation in massive scale and water scarcity become serious problems which are beyond the farmer's capacity to solve in Libya.

In order to plan an adequate land management, ICARDA introduces some new water techniques to be studied in research and development activities.

A long-term strategy stressing the necessity to conserve the national soil resources and to harvest the surface water resources was set up. The conservation measures planned are of different types and tend to be site specific and tailored to fit in with the local farming systems, customs and environmental conditions. They are classified in directly productive measures (tree plantation, crop rotation, mulching, Meskat, contour farming…), indirectly productive measures (contour banks, terraces, stone bunds …) and water management interventions (cisterns, ponds, small farm dams…).

An integrated approach has been developed for the selection and characterization of benchmark watersheds (biophysical and socioeconomic aspects). Site selection is done through analysis using geographic information, systems (GIS), surveys, and rapid rural appraisal to build a comprehensive database that is useful for integrated watershed monitoring, assessment and management.

A multi-criteria participatory approach was applied, which includes activities in planning, research and training as well as in project implementation and monitoring. All the activities were carried out in close cooperation between ICARDA and the Libyan national Research Center.

Four pilot watersheds were identified as most suitable and within these watersheds four pilot sites were selected in 2010 to constitute pilot projects for demonstration. Various criteria have been taken into consideration to decide on priorities such as accessibility, acceptability by beneficiaries, expected participation of farmers, climate, soil and topography.

Key words: Management, erosion, conservation, soil, water, criteria, techniques.

Introduction:

Since longtime, water harvesting systems were implemented in areas where annual rainfall exceeds 150 mm. Libyan ancestors faced water scarcity long time ago and the problem has been treated during the Roman, Greek and Islamic empires (Abdelgawad, 2009).

Indigenous water harvesting systems are found everywhere above 150 mm of rainfall in different systems. Since at least Roman times runoff farming water harvesting techniques were applied extensively in North Africa. Archeological research by the UNESCO Libyan Valleys team revealed that the wealth of the "granary of the Roman empire" was largely based on runoff irrigation (Gilbertson, 1986).

Poor farming practices, overgrazing and increased occurrences of drought, have all played a role in the decline of land productivity in Libya. Soil degradation and falling groundwater tables let

the situation of natural resources become very critical. This represents a crucial danger for the sustained production of food.

A major critical problem of agriculture in much of Libya is the recurring deficiency of soil moisture for crops and range production. Libya is one of the world countries that have water scarcity problems. Most of the territory of Libya is located in the arid and semi-arid climatic zones. The available renewable water per Capt. is 150 cubic meters in 1995; it will decrease to 70 cubic meters in 2025 (Abdelgawad, 2009).

The underground resource composes more than 97% of total water in different uses in Libya. This underground resource is divided into two sections: renewable and nonrenewable resources. The renewable resources are those which receive annual recharge. They are located in the Northern of Libya in Jabal Gharbi, in Al Jabal Al Akhdar and in Al Hammda Al Hamra. The amount of annual recharge is about 650 million cubic meters (Abdelgawad, 2009). This amount is utilized completely by water wells and consumption is higher than the recharge, causing a continuous decline of the water table.

The soils have not developed profiles in most cases due to climatic conditions which are arid and semi arid with low rainfall, high temperature and wind which have great effect on vegetative growth (Abdelgawad et. al, 2004).

The danger of water loss and land degradation has been given considerable concern in the programs planned by ICARDA in Libya. Since 2010, Different techniques of soil and water conservation have been adopted and were established in order to maintain soil fertility and to improve its productivity.

1- Planning for strategies of Soil and Water Conservation:

Water and soil conservation needs to be an essential component of all rural development projects. It is recognised as a necessity to protect hydraulic infrastructures and to expand their lifetime. It is also admitted that for rural development projects, soil conservation practices are the major rural employment creating activities.

A long-term strategy stressing the necessity to conserve the national soil resources and to protect the existing infrastructure was set up through the collaboration of Libyan national institutions with ICARDA.

Integrated benchmark research watersheds were selected with suitable sites for water harvesting and soil conservation techniques taking into consideration the biophysical and socio-economic characteristics.

The conservation measures proposed are of different types and tend to be site specific and tailored to fit in with the local farming systems, customs and environmental conditions.

In order to reach the objectives of an adequate land management, ICARDA managed a research and development project. The project aims to an appropriate land and water management in areas suitable for arable cropping in Libya. An integrated approach was adopted, in order to contribute effectively to the socio-economical development of the country.

In order to carry this into effect, ICARDA supports Libyan authorities since 2010 in introducing rainwater harvesting techniques, partially combined with supplemental irrigation and soil and water conservation.

2- Methodology for selecting suitable watersheds

The available data on the climate, soil, topography, land use and human interventions could be very helpful in planning water harvesting structures in the project area. This data can be collected

from various sources such as studies, thematic maps, aerial photos, satellite images and through field visits, site inspections and geographic information systems (GIS). It is also very important to treat and analyse the farming practises of the local society in order to recommend management practices that allow productivity improvement and farmers' income increase. This will help for adopting the proposed techniques by the farmers.

An improved methodology has been developed and applied to identify suitable watersheds based on integrated water resources management concept. The approach integrates multidisciplinary knowledge, GIS utilities, and verification and validation in the field to develop and test a methodology to identify watersheds with specific characteristics. The potential watersheds were studied and optimal sites were selected to implement water harvesting techniques and to undertake research on the three project components: (i) integrating rainwater harvesting in the agricultural systems for improved productivity; (ii) integrated improvement of wheat and barley-based cropping systems in rainfed and irrigated areas; (iii) improvement of small ruminant productivity; in addition to cross-cutting socioeconomic component (F. Ziadat, 2012).

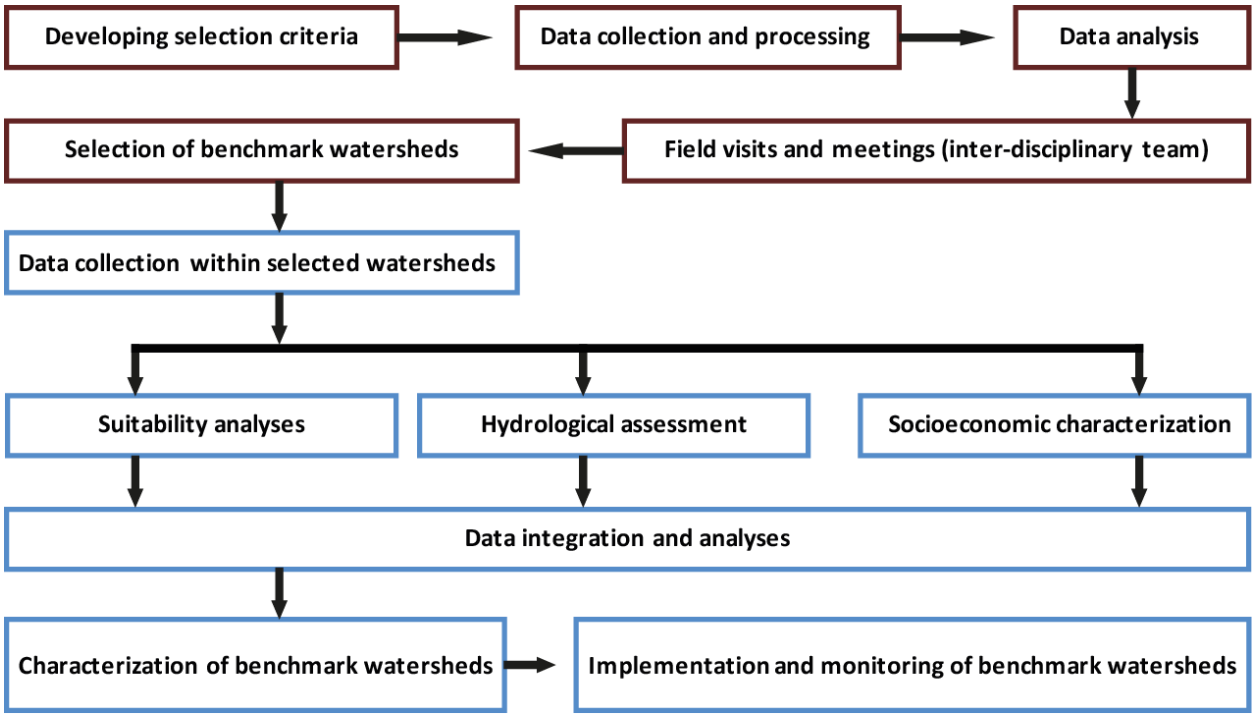

Fig.1 ***Benchmark Watershed Selection and Characterization Simplified***

3- Modelling and selection of research sites:

The main objective was to find representative sites of the watersheds proposed for a plan of soil and water conservation techniques. The problem of lack of data (rainfall, soils, topography, hydrology...) led the scientists in charge of this activity to take into consideration water harvesting, livestock production, new crop varieties and new cropping systems.

Site selection was done in three stages: analysis using geographic information systems (GIS), surveys and rapid rural appraisal. The indicators for selection have been determined and the area scanned in a large scale (97000 km^2) using the available data in the watershed: rainfall, population distribution, topography, land use and other factors (F. Ziadat, 2012).

The proposed watersheds have been visited by multidisciplinary teams, to validate the available data collected and to improve the selection approach by taking into consideration the accessibility, existing and potential cropping systems, water resources, microclimates, soil type, depth and slope, and community characteristics. Using this information, detailed models have been created to analyse the local hydrology and land suitability. Field visits have been organized to all the potential sites. Rural appraisal techniques permit to collect biophysical and socioeconomic data in a multi-criteria participatory approach with the different beneficiaries. The final project sites were selected after detailed environmental and socioeconomic analyses.
The selection process was flexible to take into consideration the interactions with farmers, and multidisciplinary to better understand the interactions between diverse system components.
After multiple iterations, ideal sites were selected with appropriate technology packages for each one. Data gaps were filled using local knowledge gathered from farmers, extension experts, community organizations and the local administration.
The watersheds have then been characterized both for physical and socioeconomic conditions and four sites representing the optimal solution have been selected: Two in the eastern part of Libya (Al Marj and Samalous) and two in the western part (Gadama and Turghut-Ghanema).

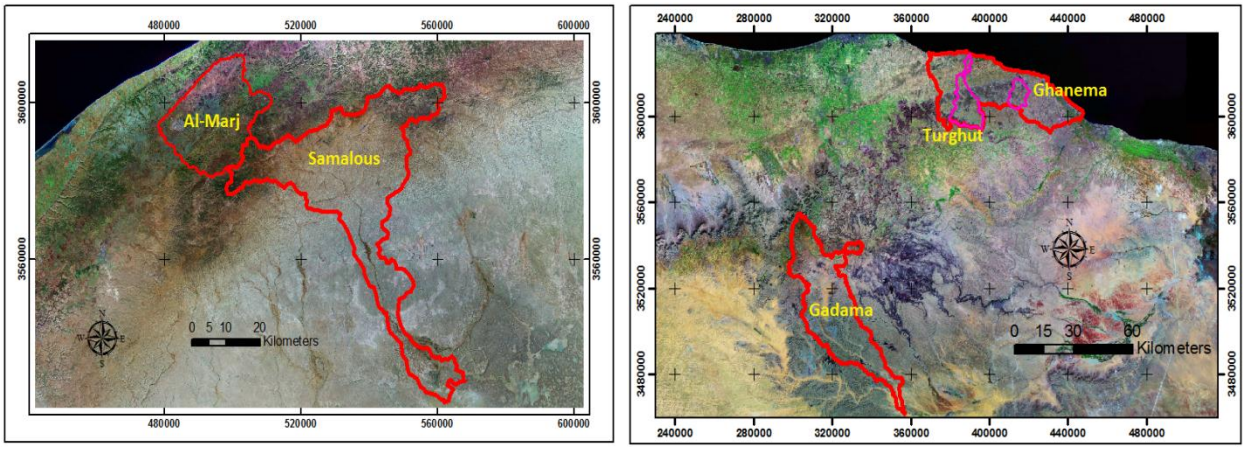

Fig.2 ***Selected watersheds for water harvesting***

4- Water harvesting selection process:

After selecting the suitable sites for water harvesting, ICARDA proposed to the national administration a program to invest in soil conservation and water harvesting. The introduction of new farming policies based on the use of technology and adequate farming practices were adopted in order to conserve the soil and improve its productivity.
Identification and design of appropriate water harvesting techniques suitable for various conditions within the pilot watersheds was based on technical and socioeconomic evaluation. Micro and macro catchments water harvesting technologies such as surface and subsurface reservoirs, contour ridges, cisterns, etc have been considered and designed. Planning and designing the systems have taken into consideration prevailing cropping patterns and the integration of the recommended technologies in the existing agricultural systems (D. Prinz, 2010).

The process permit to select 21 suitable water harvesting (WH) techniques both at the micro- and macro-levels in the four selected watersheds, and to design the selected water harvesting structures and techniques and provide construction specifications and drawing sketches. 6 basic criteria have been taken into account (D. Prinz, 2010, Fig.3); the participation and general acceptability of the beneficiaries depend strongly on the economic and social situation of the farmers.

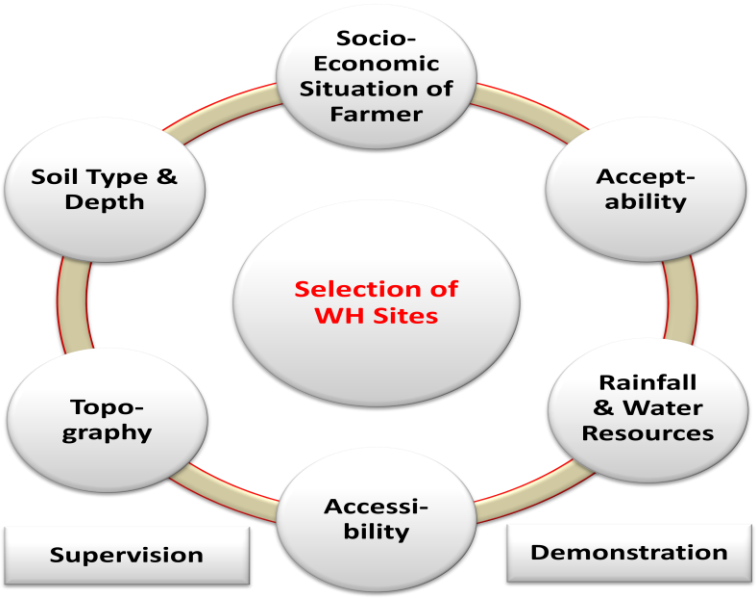

Fig.3 ***Basic criteria for site selection***

5- Objectives of soil conservation and water harvesting plan in Libya:

The soil conservation and water harvesting interventions, as planned for in the management plan have covered different regions and proposed to reach an ambitious objective, particularity due to the fact that the water harvesting interventions call not only for mechanical and physical measures such as (terraces, semi-circular bunds, cisterns, hill lakes...) but also agricultural developing interventions (fruit tree planting, forage crop, range management, change in crop production) with an effective farmers' participation .

The objectives of the proposed water harvesting and soil conservation plan are:

1- To reduce the loss arable land.

2- To maintain soil fertility in order to avoid the decrease in soil productivity.

3- To retain the runoff water (which are actually lost in the sea and lakes).

4- To recover arable land by establishing structures in the arid areas.

5- To reduce damages caused in valleys and plains by floods.

6- To implement a new farming policy, this aims at implementing WH structures in order to increase production.

The locations of the sites were chosen not only to satisfy the basic criteria, but also to be well suited for demonstration and research purposes.

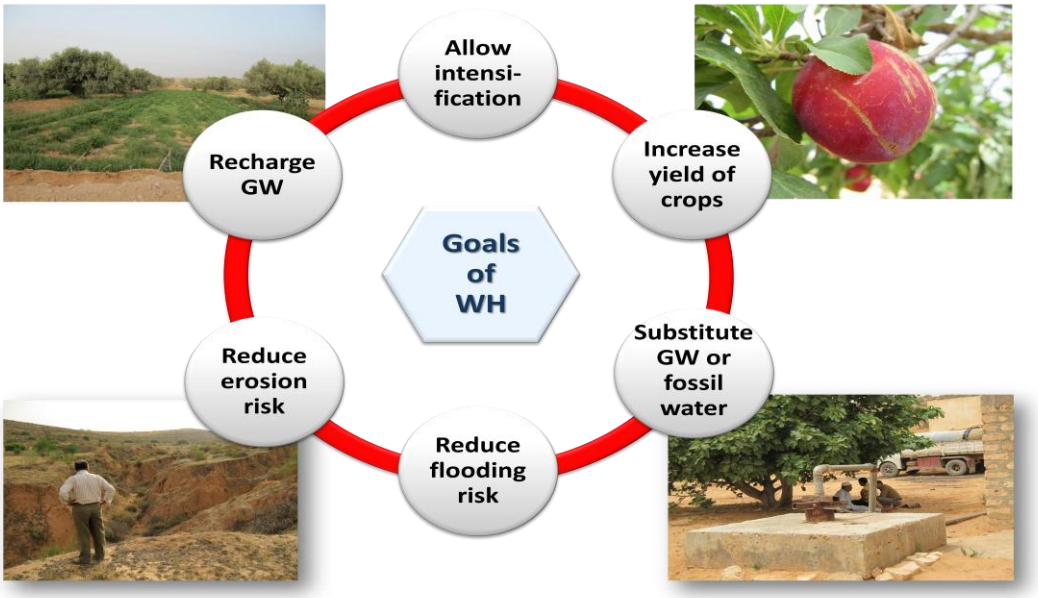

Fig.4 ***Goals of water harvesting interventions in the four selected watersheds***

6- An Integrated Approach:

In order to reach the objectives of an adequate water harvesting management, an integrated approach, based on a methodological study and a planning, which permit to find practical and rational solutions to the problems of lack of water, was adopted.

The approach is to protect the downstream of watersheds from sedimentation, and floods, and to improve revenues of farmers and livestock herders established in the upper parts of the watersheds. The integrated conservation management was considered at three levels:

- Technical: It is fundamental to define guidelines to help in harvesting water and preventing and treating soil erosion, and to consider the watershed management techniques which aim at maintaining the fertility of the soil in the watershed and reducing the transport of sediment.
- Economical: In order to make the best micro and macro economical return of the conservation work, it is crucially important to count on the participation of the land-user. It is not expected that this one will change his usual practices unless he perceives that the change is directed towards his interests, that it will minimise his risks and increase his income.

At the macro level, the aim consists of meeting the government objectives of controlling the critical soil erosion situation, harvesting the available water resources, moving towards food self sufficiency, and ensuring the best global ratio cost-benefit of the government's investments.

- Social level: concern was given to the support of the local population, as the objective is not only harvest water and promote economic growth but is also related to the improvement of the public's conditions especially in the areas seriously affected by erosion and lack of water. Successful water and land resources management involves the introduction of changes in farmers' behavioural patterns.

As only integrated concepts can be sustainable, the general idea of the planning and implementation process was integration: All the proposed measures have considered 'Water Harvesting' (WH) as an integral element of rainfed and irrigated farming as well as of the natural environment, it should fit to the prevailing socio-economic conditions, integrating the needs of

tree crops, annual crops (such as barley) and small ruminants and trying to optimize the overall resource use.

6- Implementation of water harvesting techniques:

6.1- Sites selection

The identification and design of appropriate water harvesting techniques suitable for various conditions within the pilot watersheds was based on technical and socioeconomic evaluation. Micro and macro catchments water harvesting technologies such as surface and subsurface reservoirs, contour ridges, cisterns, etc. were considered and designed. Planning and designing the systems took into consideration prevailing cropping patterns and the integration of the recommended technologies in the existing agricultural systems.

Different water harvesting techniques were proposed for the 21 selected sites to collect rainwater and runoff. The additional amount of surface water resources will be used for the irrigation of annual crops, pastures and trees and domestic and livestock consumption and groundwater recharge. 4 Sites were selected to implement representative techniques for the entire watershed and to be considered as pilot sites: Jendouba research station, Santosa, Subwatershed Ghanema, Farm of Mahmoud Balal Al-Mahdi and Wadi Al Mssud Subwatershed.

6.1- Approach

A multi-criteria participatory approach was applied, which includes activities in planning, research and training as well as in project implementation and monitoring. All activities are carried out in close cooperation between ICARDA and the national Agricultural Research Center.

Fig 5 and 6: ***ICARDA staff, local researchers and beneficiaries discussing suitable Water Harvesting intrventions***

The characterisation of the selected sites was done and all the physical indicators were established. For example the farm of Mahmoud Balal Al-Mahdi is located in the subwatershed Sidi Salim in Al Marj watershed. The site is located in a rather flat valley between largely eroded hills. The altitude is about 415 m. The suitable area covers about 4 hectares. The farm area amounts to about 180 hectares, out of which 85 hectares are suitable for arable cropping; the rest

is sparsely forested hilly land. Terra rossa is the dominant soil type with a depth exceeding 50 cm. High infiltration rate reduces runoff significantly. The rainfall is about 300-350 mm per year. The slope average is around 5%. We give an overview over the major measures to apply at this site in table1.

Table1. ***Measures proposed at the selected site of Mahmoud Balal's farm in Al-Mhadi***

Objectives	**Measures to Apply**	**Remarks**
Grain crop improvement	Interrow WH for barley	The site is located at the foot of a sparsely vegetated hill and receives runoff from two sides, a typical situation for this part of the watershed
Improved tree & bush crop production	Contour bunds	
	Semi-circular bunds	
	Meskat System	
Low cost water storage	Pond / basin construction	Stored water to be applied by hose pipe
Wadi / erosion gully stabilization	Checkdams; runoff use for water storage.	Gully edges can be planted to trees
Reducing crop evapotrans-piration	Shelterbelts with micro-catchments	In first 2 – 3 years irrigated with tank-water

Different water harvesting techniques were proposed for this pilot site as indicated and in one from the experiments contour bunds and semi-circular Bunds have been implemented with the objective to introduce three different fruit tree crops (apples, peaches, and apricots) and to find the optimal combinations (fig 5).

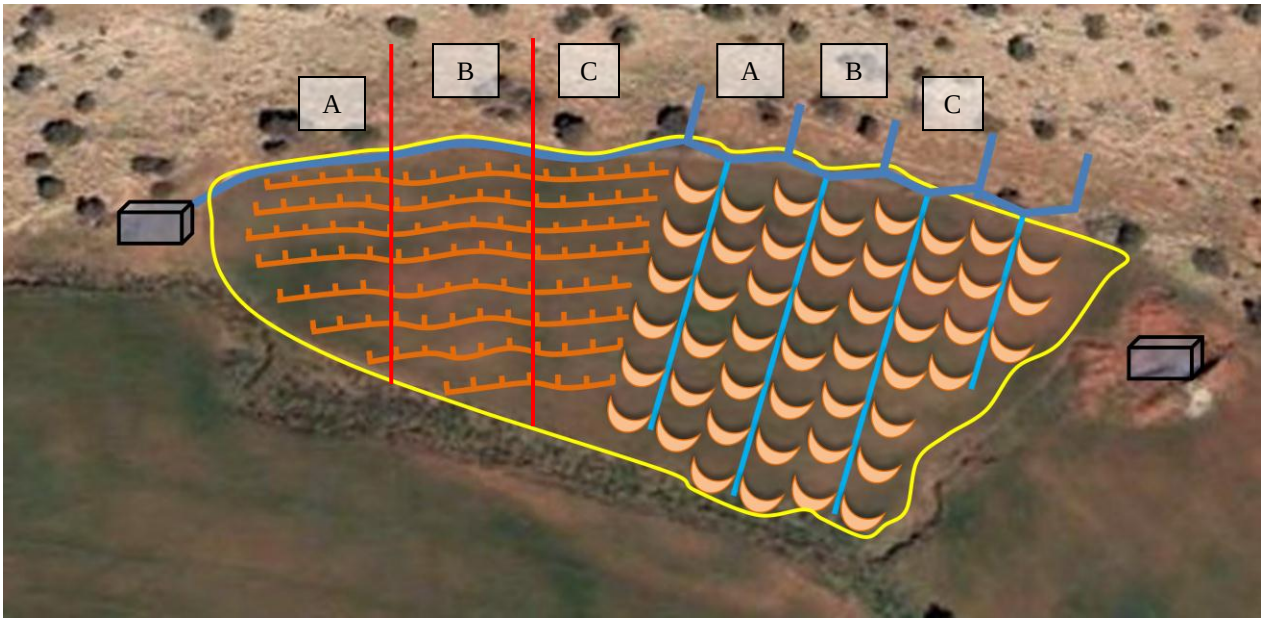

Fig.7: Two methods of Water Harvesting, applied to apple (A), peach (B) and apricot (C) trees, are tested at Mahmoud Balal's farm in Al-Mahdi

6.3- Implementation of water harvesting techniques:

In 2010 four pilot watersheds were identified as most suitable and within these watersheds four pilot sites were selected in 2010 to start with. Various criteria have been taken into consideration to decide on priorities such as accessibility, acceptability by beneficiaries, expected participation

of farmers, climate, soil, and topography. The solutions found in close cooperation with the farming community shall be spread nation-wide (M. Boufaroua et Al. 2012).
All the selected sites in the planning level (21 sites in the 4 watersheds) were visited and different scenarios of management were discussed with the beneficiaries and the extension local experts in charge of the implementation. Aiming to validate the proposed techniques with the practical conditions in the field, the technical scenarios were reviewed on site with all the partners.
A classification has been done on site. Different criteria were taken into account to decide on the priorities: accessibility, acceptability of beneficiaries, expected participation of farmers, climate, soil, topography (M. Boufaroua et Al. 2012).
The selected water harvesting measures are of different types and tend to be site specific and tailored to fit in with the local farming systems, customs and environmental conditions. The proposed techniques were implemented using the available resources on site. This exercise was done for the different sites by the water harvesting team in each pilot project with the participation of the beneficiaries.
To be sure of the success of the implementation, all the members of the national WH team have participated in the process. Each member in charge of a pilot project and has studied and analysed the available data generated from the study report of the entire watershed (planning level). Any gap in the collected data has been filled through meetings organized with farmers in the different sites.
The multidisciplinary teams have worked in a participatory approach and proposed the following activities:

- Summary on the physical and socioeconomic information of each selected site in a homogenized form presenting the technical details of the proposed techniques.
- Main information about every site: accessibility, soil type, topography (slope percentage), surface, hydrology and land use.
- Modalities of implementation: contract with farmer, administration, specialist or company.
- Tools needed, number of workers, existence of companies experimented in WH and, experimented farmers in WH.
- Estimation of the budget cost by site for approval.

Meetings have been organized with the farmers on the selected sites and the beneficiaries have been associated in all the steps of the implementation phase.
The implementation process has been done with the participation of different partners. The local team members have been trained (theoretical and on job trainings) to follow on all the stages of the implementation process and they are actually able to conduct the planned works and to assure the training of the members of other regions.
Various techniques of soil and water conservation were implemented such as: contour bunds, semi-circular bunds, meskat, contour bench terraces, valerani, etc. The water harvesting team has highly coordinated with the range land and socioeconomic teams and agree about the techniques to implement and the type of plantation to use for consolidation.

Fig7: ***On job training for the local staff and the beneficiaries (Photo of December 2010)***

Fig8: ***Inter-row-Water Harvesting (Photo of January 2011)***

CONCLUSION:

The concept of a moral obligation to care for and harvest water for better production for food security for the future generations has incited the Libyan scientists to invest more in the water harvesting and conservation of soil. ICARDA's specialists have been involved to establish integrated research systems in 4 watershed benchmarks with characterization and baseline information. Suitable water harvesting structures were designed and implemented in one representative site in each watershed with establishing reference conditions of the biophysical information in the watersheds selected, collated and organized in a database and research parameters were identified to evaluate economic and environmental returns, increase rainfed cereals yields by increasing water, land and other inputs productivity through optimal supplemental irrigation.

This work was done in a multi-criteria participatory approach with the participation of the beneficiaries and several on job trainings were organized. The trained staff could be responsible of an adequate land management, based on an integrated approach, based on a methodological study and a planning, which permit to find practical and rational solutions to the problems encountered in his region.

A monitoring system for the implemented sites is designed. The monitoring is done at plot size to suit some systems and at hill-slope (sub-watersheds) for others. The effect of the different water harvesting systems in soil erosion and runoff will be evaluated.

If some significant success has been achieved in the field in term of soil and water harvesting and training, there are still a number of constraints to overcome. It is admitted that there is still a need for more long-term programmes, for more flexibility in project designs and for better involvement and participation of farmers in all stages of planning, implementation and maintenance.

More attention is also given for more effective forms of communication and better extension and research services to reach a larger public and call their enthusiastic participation.

To reach the objectives of an adequate land management, an integrated approach to find practical and rational solutions to the problems encountered in the struggle against erosion, needs be adopted in the national scale.

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