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Farmers' verification of improved land-use alternatives in the transitional *Badia* of Jordan

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Abstract

Decisions on land-use sustainability are particularly critical in fragile semi-arid regions of the world, especially those involving the social factor: people and communities. Typical of such an area is the Middle East region, especially Jordan which is beset by climatic constraints. New land-use alternatives were introduced by the Jordan Arid Zone Productivity Project (JAZPP) to improve land productivity in the arid to semi-arid (transitional *Badia*) land in Jordan. These alternatives were verified within experimental stations under controlled conditions. Dissemination of these findings would be successful if they suit the needs and resources of farmers. Therefore, verification of the success of these techniques under a wide range of biophysical and socio-economic conditions was necessary to judge their suitability to the target area. Various interventions were implemented on 14 sites that represent different biophysical and socio-economic conditions over the study area. With close monitoring and follow-up, successful and encouraging results were reported during the first season, even with lower rainfall than average, suggesting that these techniques were biophysically suitable for the target area. During the second season, maintenance and guarding were assigned to the farmers. Seven out of the 14 sites failed for various reasons: multiownership regime, reluctance of farmers to adopt new land use and insufficient protection and/or guarding measures. The study highlighted the importance of the farmers' comments and discussion of their specific problems and needs. This helped to improve these interventions to suit the farmers' requirements and may be important in facilitating widespread adoption and sustainability of these new land-use alternatives in the Jordanian *Badia* as well as in other areas of similar environment.

Key words: arid to semi-arid regions, land and water management, water harvesting, participatory approach, land ownership

Introduction

The transitional *Badia* in Jordan represents areas located between arid and semi-arid regions (areas receiving 100–200 mm of annual rainfall). The arid and semi-arid areas represent about 26% of the global area of the Earth (about 38.25 million km^2)[1]. In addition to its importance as a natural resource asset in Jordan, the transitional *Badia* is considered as a buffer zone that plays a major role in protecting the productive land bordering this area toward the west from desertification threats. The inadequate amount and unfavorable distribution of precipitation, coupled with poor management and uncontrolled grazing practices, are resulting in poor vegetation cover and accelerated land degradation. The current management of land and water resources in that area is not sufficient to cope with these challenges. The Jordanian transitional *Badia* covers an area of 1,200,000 hectares, which constitutes 15% of the total area of Jordan (Fig. 1). It has a potential for development and represents a viable and strategic asset for the country[2–4]. The main characteristics of this area are low annual rainfall (100–200 mm) with uneven distribution and high intensity. Soils are highly susceptible to dispersion and capping[5]. Water infiltration is thus very low; therefore, low to moderate rainstorms can lead to considerable runoff. Coupled with very high evapotranspiration rates, this results in little moisture being available for plants. It has been estimated that if the runoff water is effectively used for supplementary irrigation, it would be sufficient for some 75,000 additional hectares of barley (*Hordeum marinum* L.), which would generate 370,000 tonnes of dry matter biomass. Thus, current production figures are far below satisfactory levels[2]. Various production techniques were introduced by the

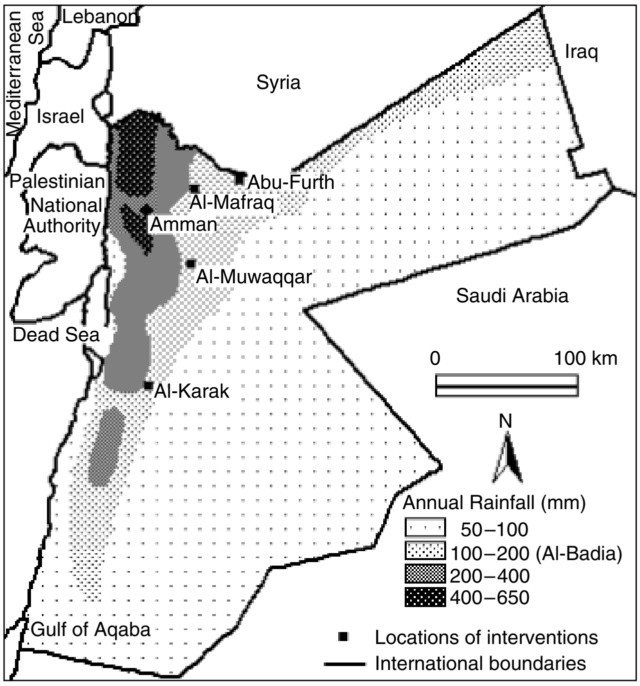

Figure 1. Locations of the intervention sites within the Jordanian transitional *Badia* region (100–200 mm rainfall).

Jordan Arid Zone Productivity Project (JAZPP) and implemented in controlled field trials at research stations[2], but were not tested in the farmers' fields. The aim of these interventions was to improve land productivity in the transitional *Badia*. However, it was necessary to verify these interventions with more emphasis on performance in farmers' fields. On-farm testing and validation of technologies developed under controlled conditions (on-station) were recommended in order to identify any constraints to adoption[6].

The study area is dominated by stony and rocky land (39%) and rangeland (33%). Rainfed agriculture, mainly barley cultivation, occupies 23%, urban and associated land occupies 2%, and irrigated agriculture (from pumped well-water) occupies only 3%. The whole range area is heavily overgrazed and shows very low productivity (about 150 kg dry matter ha^{-1})[2]. Barley is cultivated in the area as a means for protecting the land from uncontrolled grazing (by intruders), i.e., as a tradition of claiming the ownership of land in the *Badia* area[2]. This has led to an increase in the area of better land that is used to cultivate barley, even though, with time, barley yields fall below vegetation yields of uncultivated rangeland. Thus, the current productivity of the transitional *Badia* area is much lower than the potential productivity, due to the above-mentioned biophysical conditions prevailing in the area, in addition to the following three factors[2]. First, what is known as 'free-for-all' grazing, which discourages any government or private investment in land improvement. Second, zero-input barley cultivation, leading to decreased infiltration, higher runoff and decreased yields. Third, land fragmentation and absentee land ownership, which prevents proper land management.

Incorporating water harvesting technologies in the current agro-pastoral system in the *Badia* was identified as a possible tool to sustain the agricultural productivity[4]. However, there were some obstacles in applying water-harvesting interventions, such as rainfall variability and the associated risk of failure, which might require more efforts to convince the farmers to adopt the JAZPP interventions. Therefore, the proposed land-use system must be flexible to cope with such practical challenges, and must consider the human component in order to be sustainable[7–9]. The production system must be economically and socially acceptable, and also nature- and environment-friendly. Public participation in land-use planning has many positive impacts, such as avoiding mistakes, avoiding conflicts among land users, and preventing irreversible damage to natural resources. There is a growing interest in promoting the interaction between all stakeholders and scientists, to decide on proper land use and management. Direct dissemination of knowledge in one way from scientists to farmers has proved ineffective[8,9].

The Participatory Rural Approach has been recognized as an essential ingredient to agricultural development; it begins with the recognition that farmers only adopt practices that meet their perceived needs. The process recognizes the need for communication links between all interested parties in defining goals, management policy, and solutions to problems[10]. With the current emphasis on environmental and economic sustainability of agriculture, there is a need for a more integrated approach. Participatory research helps to bring scientific methods and the integrated production needs of farmers together to develop practical, effective and carefully tested farming methods[11]. The objectives of this research were to investigate the possibility of adoption of the land-use alternatives by farmers, and to identify their suitability under field conditions.

Approach and Methodology

Selection of suitable sites

Selection of potential sites and farmers for field trials was based on the following criteria: the site should represent the typical prevailing conditions in the transitional *Badia* zone, it should be accessible and visible to as many members of the farming community as possible in order to maximize local awareness, and it should be currently cultivated by a cooperative farmer who lives in the area. The possible locations suggested by the various organizations, local people and/or field officers (from Agricultural Extension Departments) were visited and assessed. Sites were first assessed based on their physical suitability for the planned use, and then the willingness and ability of the owner(s) to cooperate with the program were verified.

The criteria used for the physical assessment included: *slope*, which determined which intervention(s) could not be installed; *soil depth*, which determined the suitable crop and how much water the profile could store; *rock outcrop*

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Table 1. Different designs of water harvesting techniques used in the study.

Intervention[1]	Width of catchment strip (m)	Width of cultivated strip (m)	Catchment : Cultivated
Contour ridges	10	5	2 : 1
Contour ridges	15	5	3 : 1
Contour furrows	3	0.5	6 : 1

[1] Contour ridges, atriplex cultivated in contour ridges and barley in a part of the catchment area above ridges. Contour furrows, barley alone inside the contour furrows.

and *soil surface stone cover*, which have implications for tillage and cultivation; *infiltration rate/runoff*, as indicated by surface capping/absence of surface structure. In addition, the following social factors were also considered: *land fragmentation*, how many owners claimed title to the land; and *visibility/proximity*, to the target group (farmers).

Three broad zones of the *Badia* were included, the northern, central and the southern areas. The soils of these areas are derived from limestone and/or basaltic parent materials[12]. The elevation ranges from 700 to 1200 m above sea level. All proposed sites were visited and the following information was collected either from the field or extracted from the JOSCIS database[12]: location, elevation, soil series, precipitation, frost days, area available to install the intervention, soil salinity, surface capping, surface cracking, erosion, stone cover, rock outcrop, slope steepness and curvature, previous and current land use, population density, families on land, family size, livestock, total land holding and fencing requirements. The information collected was used to undertake a potential land suitability assessment for the intended Land Utilization Type (water-harvesting intervention).

The purpose of the field trials program was explained to owners of the sites that were considered suitable. The decision about including the farmers' land was taken based on the farmers' willingness for cooperation, the proportion of land that could be used for the trial without putting the farm under risk (minimum of 1 hectare), capability of farmers to maintain and protect the trial, and sufficient family labor support. In total, some 38 sites were initially assessed.

Of these 38 sites, 24 sites were rejected outright for various reasons; some sites were physically unsuitable; some sites had an obvious ownership and/or land fragmentation problems; and some were not accessible and therefore not visible by the farming community. Biophysical suitability and socio-economic factors were both considered in determining the overall suitability of the site. Only 14 sites continued to the end of the first season. Details about the implementation of the four interventions are explained in the following paragraphs.

Micro-catchments for tree crops (*Negarim*). Many sites were identified as suitable for micro-catchments based on biophysical criteria. However, several sites were deemed unsuitable due to ownership and/or land fragmentation problems, which resulted in implementing this intervention in only seven sites. The FAO formula[13] was utilized to design the size of the micro-catchment diamond, which ranged between 64 and 144 m^2. The micro-catchments were constructed using soil ridges (30 cm wide and 40 cm high). The tree seedlings were planted in an infiltration pit that was excavated at the lowest point within each micro-catchment.

Contour ridges for atriplex (*Atriplex nummularia* L.) and barley. Considering the biophysical factors, there was no difficulty in locating suitable sites for contour ridges. Land ownership (multiownership) was not an important reason to reject the site for this intervention. The situation was different with trees since farmers consider tree cultivation as a permanent occupation of part of the land, which complicates the later subdivision of the whole parcel between the owners. Therefore, at sites where land was owned by more than one farmer, it was recommended that contour ridges are more suitable, even when the land was physically better for micro-catchments.

The basic principle of using *catchment/cultivated area* ratios[13] was used to calculate the spacing between contour ridges, with some adjustments to consider the effect of slope steepness[14]. One strip of 5-m width was cultivated and sown with barley immediately upslope from each furrow, while the area above this was left bare to act as the catchment area. Basically, contour ridges are meant to be cultivated with atriplex only; however, due to farmers' insistence, the design was modified to accommodate barley. The sites' installation was carried out based on three different designs detailed in Table 1. Contour ridges for atriplex with barley were installed in five sites.

Contour furrows for barley. Barley was cultivated in deep furrows at three sites that were selected from the five sites where contour ridges were established. Furrows (30 cm wide and 30 cm deep) were made using a moldboard plow, and barley seeds were sown inside the furrows according to the specifications listed in Table 1.

Water spreading. The study area contains what is known as *Marrabs*, narrow areas of silty alluvial flat *wadi* bottoms that experience natural water spreading during and after periods of rainfall. Surface characteristics of some *Marrabs* are favorable for cultivation and plant growth. Although the total area of *Marrabs* is limited, appreciable biomass can be produced from these areas.

Installing a few stonewalls perpendicular to the direction of stream flow facilitates the spreading of water outside the *wadi* bed to flood the surrounding area, which allows time for water to infiltrate into the soil, thus increasing stored water in the profile. Owing to these strict site requirements for water spreading techniques, only two sites were found suitable. The spacing between stonewalls was 8 m, which was based on the calculation using the FAO methodology[13] with some adjustments to account for surface capping and surface stoniness that are important features in the Jordanian *Badia* area[5].

Monitoring and evaluation of interventions

A number of field officers were trained to monitor, control and collect data about the interventions. Contact with farmers was maintained before and after the installation of the interventions through routine visits by researchers and field officers to monitor the performance of the crop or vegetation being grown and the manner in which the test site was managed and maintained, and to respond to any practical or technical questions raised by the farmer. Farmers were visited regularly every 2 weeks. Extra visits were encouraged after any significant rainfall event, in case there was unexpected damage, or during periods of poor rainfall, in case advice on limited supplementary irrigation (from nearby wells) had to be given.

The following aspects were recorded during each monitoring visit: precipitation, irrigation (if any), status of the catchment area, status of the collection area, damage (cause and need for maintenance), and visual estimates of crop performance. Three field days, attended by collaborators (NGOs, local organizations and leaders) and other innovative farmers, were organized to demonstrate what the project had achieved and to gauge the farmers' reactions to the success or otherwise of the measures implemented. Dissemination strategies might benefit by including such farmers in leadership roles in the initial stage of education programs[15].

Results and Discussion

The late start of rainfall during the first season (toward the end of December) adversely affected the Project activities, particularly in the south (Sites 1, 2, 26, 27 and 28). Total rainfall was only 113 mm, which was below the long-term average (150 mm). Moreover, the rainfall occurred mainly as small showers, which were ineffective in generating runoff for water harvesting. The proportion of rain events leading to significant runoff was much lower than normal. Runoff coefficients were approximated using results from previous research[16]. The overall approximated runoff coefficient did not exceed 23% of the total rainfall, which was lower than the 15-year average (33%). A long dry period in late February through March and a prolonged period of higher than normal temperatures led to relatively poor crop growth over this period.

Trials results

Considering the late start of the rainy season, lower rainfall and much lower runoff volumes than average, the performance of the trials (crop stand, density and survival rates) was encouraging compared with the surrounding fields, as evaluated by farmers, Extension officers, and other observers. A summary of intervention status during the first and the second seasons is presented in Table 2.

Micro-catchments for tree crops (*Negarim*). These interventions were implemented successfully, and growth of tree seedlings appeared encouraging (Fig. 2a). At the end of the first season, all interventions were successful with survival rates between 95 and 100% (Table 2). This proved that these interventions performed well from a technical (biophysical) point of view. The close monitoring by project staff, good protection and guarding of the sites and the benefit of limited supplementary irrigation (during the establishment stage) helped in this success, even with low rainfall amounts. In the second season, where farmers were fully responsible, without any monitoring by project staff, the outcome was not as successful; three sites were total failures (Sites 1, 2 and 28, survival 0%), two sites were relatively successful (Sites 24 and 34, survival 70%), and only two sites were successful (Sites 9 and 26, survival 100%).

The unsuccessful sites were abandoned by the farmers for different reasons, mainly because the cultivated land was only part of a land parcel owned by many owners. None of the owners felt responsible for that particular land, and therefore no protection or maintenance was provided, which resulted in damage by livestock. Fencing alone without guarding was not enough to avoid the damage. This highlighted the importance of social factors in the sustainability of the water-harvesting interventions; technically successful intervention could fail without farmers' input.

In another situation (Site 28), the land was owned by one farmer and the intervention failed. The land was assessed as suitable for contour ridges but the farmer insisted in installing micro-catchments with olive (*Olea europaea* L.) trees, because the land was an extension to an already existing irrigated olive farm. The performance of olive trees under water harvesting was unsatisfactory for the farmer. Therefore, the farmer decided that this intervention was a waste of his land, while he could cultivate it with a higher number of trees under irrigation, although from an unsustainable water source (groundwater resources). This indicates that while it is important to screen the land-use alternatives against the farmer's priorities and wishes, the biophysical suitability of land for certain purposes must not be ignored. Alternatively, compromised solutions must be found between both aspects whenever they are in conflict.

Absence of proper maintenance during the second season was the main reason for the relative failure of two sites. Losing interest and enthusiasm due to either ownership complications or no obvious benefits in the short-term

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Table 2. Intervention status during the two growing seasons.

Site no.	Intervention and crop[1]	Location (city)	Rainfall (mm)		Irrigation (liters per tree)		Survival/ germination (%)		Crop height (cm)		Remarks
			2001	2002	2001	2002	2001	2002	2001	2002	
1	MC/Olive	Al-Karak	165	170	40	0	100	0	50	0	Multiownership, no guarding and/or protection, damage by livestock
2	MC/Almond	Al-Karak	165	170	40	0	100	0	50	0	Multiownership, no guarding and/or protection, damage by livestock
9	MC/Olive	Al-Muwaqqar	127	149	0	0	95	95	99	115	Successful, single owner
24	MC/Olive	Abu-Furth	94	128	60	0	100	70	80	80	Successful even without farmer's input
26	MC/Olive	Al-Karak	165	170	60	50	100	100	50	95	Successful, interested farmer
28	MC/Olive	Al-Karak	165	170	60	0	100	0	50	0	Suitable for CR but farmer demanded MC
34	MC/Olive	Al-Muwaqqar	127	149	0	0	100	70	65	70	Multiownership complication, no maintenance
18	CR/Atriplex and barley	Al-Mafraq	149	205	0	0	70	0	70	0	Suitable for MC but farmer demanded CR
19	CR/Atriplex and barley	Al-Mafraq	149	205	0	0	75	30	60	80	Successful even without farmer's input
23	CR/Atriplex and barley	Abu-Furth	94	128	0	0	86	0	40	0	No guarding and/or protection, damage by livestock
27	CR/Atriplex and barley	Al-Karak	165	170	0	0	95	0	45	0	Farmer demanded MC with trees
33	CR/Atriplex and barley	Al-Muwaqqar	127	149	0	0	50	0	60	0	Multiownership, no guarding and/or protection, damage by livestock
22	Spreading	Abu-Furth	94	128	0	0	0	70	0	20	Late installation in first season, good crop stand in second season
31	Spreading	Al-Muwaqqar	127	149	0	0	70	80	45	30	Successful even with multiownership and without maintenance

[1] Intervention and crop: MC, micro-catchments; CR, contour ridges.

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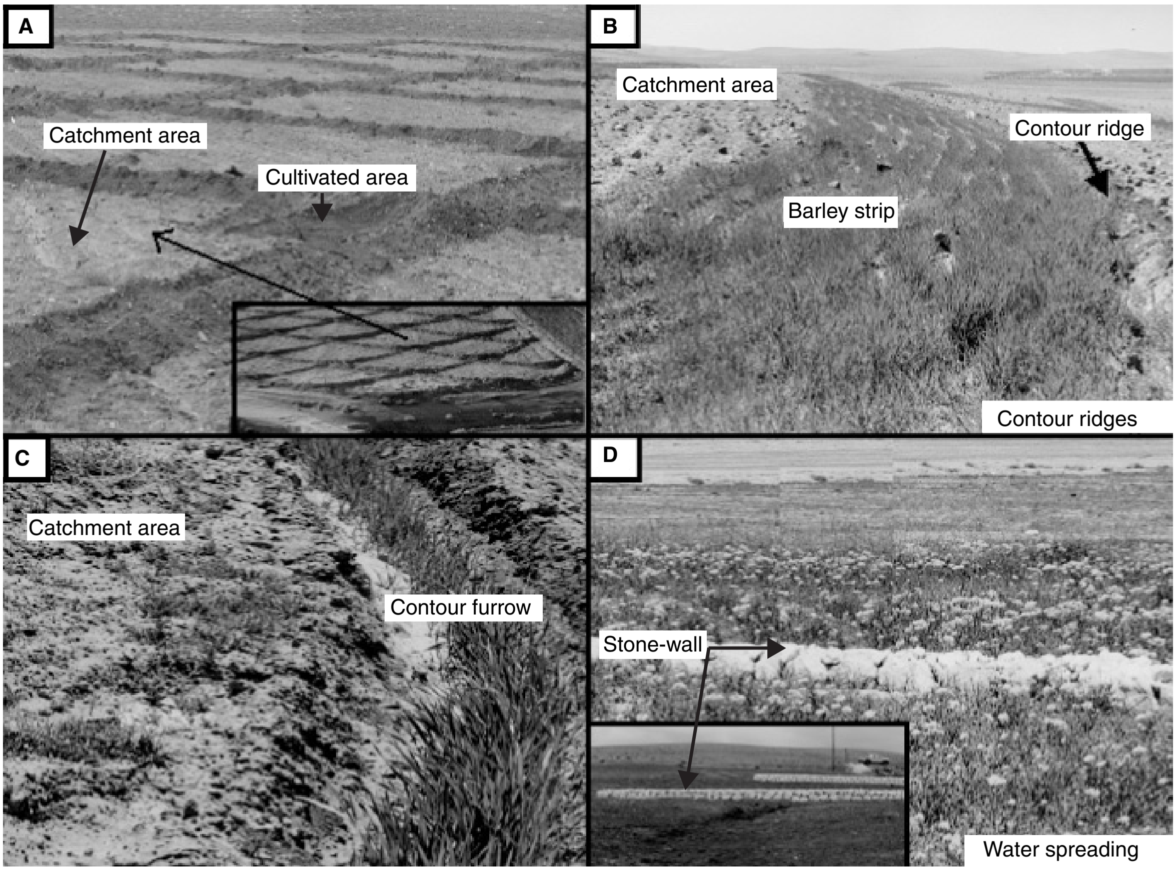

Figure 2. Intervention status during the first season. (A) Micro-catchments intervention shows the catchment area for rainfall collection and cultivated area (inset: general view of the micro-catchments intervention); (B) planting atriplex in contour furrows with barley in a part of the catchment area; (C) barley in contour furrows with no planting in the catchment area; (D) stone walls installed perpendicular to the stream bed to spread the water (inset: general view of water spreading technique).

was behind the farmers' ignorance of these interventions. However, the relative success of these interventions, even without maintenance, indicated their technical validity. Regarding the two successful sites, each of them was owned by an interested and enthusiastic sole owner. Both owners were taking the lead in maintaining and protecting the intervention. Such cases emphasized that whenever socio-economic and biophysical factors are compatible, successful implementation of new land-use alternatives is more likely. The merits of such an approach have been emphasized by others[17].

This study indicated that micro-catchments should be constructed based on an appropriate design[13] and that bunds must be compacted firmly, especially in lower areas of the diamond to avoid damage by accumulated runoff water. Continuous checking of the bunds is necessary, especially in the first season and after each appreciable rainfall event. Based on field observations, infiltration pits must be sufficiently low to collect all runoff, especially for those rainfall events with high amount and/or intensity. During the first two seasons, limited supplementary irrigation is essential, especially in dry periods, in order to increase the rooting depth as much as possible and to keep seedlings alive. Annual crops (vegetables) could be cultivated in the infiltration pits during the first few years to provide some income for the farmers until the trees start production. The layout of the micro-catchments should allow access for tractors to facilitate occasional irrigation without causing damage. Open diamonds, oriented on the contour every 20–30 m, could be the solution to this problem. Protecting the intervention from grazing (by fencing and guarding) highly improved the regeneration of natural vegetation; similar conclusions were stated by the JAZPP project[2]. Therefore, continuous weeding is required both in the catchment area and in the infiltration pit. Using the weeded vegetation as animal fodder compensates for the weeding costs.

The cost of site protection using a fence was relatively high (about 75% of the total implementation cost), and hence, it is a serious obstacle for implementation. Cheaper alternatives are thus required because fencing is vital to protect the planted trees from grazing by livestock. Such alternatives could be one or more of the following: (1) undertaking micro-catchment intervention over a large area, so that the perimeter-to-area ratio is low; this could be implemented by adjoining farmers; (2) select sites to implement this intervention to be close to the village, so that animal movements would be quickly seen; (3) growing

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cactus as a live fence, which is also a source of income, with the cactus itself being supplied with harvested water; (4) in areas where stone is easily available, and especially where family labor is possible, install stone walls, with or without a strand of barbed wire along the top of the wall, .

Contour ridges for atriplex and barley, and contour furrows for barley. These interventions were successful in improving the productivity of atriplex and barley as well as in restoring many plant species, Figures 2b and 2c are examples. No fencing was required to protect the sites, and therefore the cost of installation was relatively low. This is because the cultivation of barley is traditionally used to claim land ownership and, therefore, protects the land from intruders. The crop stand, density and survival rates were compared with adjacent lands that were cultivated by the farmers using traditional seeding methods (without water-harvesting measures). Overall, the density and stand of barley cultivated using these interventions were much better than those of barley cultivated in adjacent untreated land. The farmers also acknowledged these observations during the field days, which are explained later.

The above results, at the end of the first season, indicated good performance and suitability of these interventions to the study area. In the second season, however, the results were less successful; the farmers cultivated only one out of the five sites. In two of these sites (Sites 18 and 33), the land was assessed as suitable for micro-catchments (slope $< 3\%$) but farmers insisted on contour ridges, mainly because of ownership complications, where farmers think about tree cultivation as a 'permanent' land-utilization type. Even with installing what the farmers think as a suitable intervention, the fact that the land is owned by many farmers resulted in ignoring the intervention, and consequently no maintenance or protection was provided by the farmers. This might be due to the fact that only one of the landowners was approached and all agreements and explanations about the intervention were discussed only with him. Thus, approaching all owners would, in retrospect, have been a better alternative in order to get their approval for the work.

In another site (Site 27), the farmer wanted micro-catchments with olive trees to complete an already existing olive farm. The assessment of the land indicated total unsuitability for olive trees, and therefore barley was cultivated in that land. With low rainfall, and consequently low productivity of barley, the farmer lost interest and abandoned the intervention. The lesson learned is that a change of land-use type to a new, more suitable one, but without the farmer's agreement, is doomed to failure. Again, a compromise should be achieved between biophysical land suitability and farmers' needs and wishes in order to introduce these new interventions successfully. It has been indicated that the development of new technologies for farming systems can be greatly enhanced through more extensive use of participatory research[11].

Technically, there are some important outcomes from these interventions. Contour ridges planted with atriplex were less successful when barley was planted in a part of the collection area. However, farmers insist on cultivating barley as a means of protecting the land from any livestock grazing. Therefore, it would be rational to recommend the plantation of barley only on a limited part of the collection area, with atriplex cultivated in the contour ridges. The percentage of the collection area planted with barley could be progressively increased when the atriplex rooting system is well established. An example of this was observed in Al-Mafraq site where the farmer cultivated the whole field with barley and the atriplex shrubs in contour ridges were still very vigorous and productive during the second season. It is also possible to cultivate barley in contour furrows without atriplex, but with a wider furrow bed (80–100 cm) than the one used in this study (only 30–40 cm), in order to accommodate more seeds. Developing a machine to construct furrows with these dimensions and to plant barley at the same time is needed to popularize this technique.

Continuous maintenance of contour ridges is required throughout the rainy season to avoid erosion and losses of collected water. Small earth ties are needed every 5 m along the contour ridges or deep furrows to gain better water distribution uniformity. Continuous weeding of the collection area greatly improves the productivity of atriplex. The protection of shrubs, especially during the first season, is an important issue. Again, cheap alternatives, such as spiny varieties of cactus, must be considered for protection purposes.

Water spreading. Water spreading was very successful when practiced inside Al-Muwaqqar experimental station, where intensive vegetative cover was generated[2]. In the farmers' fields, the implementation faced some obstacles during the first season, but, with good design on suitable sites, this technique proved to be highly successful (Fig. 2d); the vegetative cover was much better than that of the surrounding un-flooded areas. The fine holes between large stones were closed using gravel so that water flow was sufficiently reduced. The construction cost was relatively high but can be reduced using the available family labor, especially when stones are locally available. The results indicated that, due to a large amount of runoff generated, the catchment area should not exceed 10 hectares when stonewalls are implemented. For areas larger than this, earth bunds with small concrete spillways can be considered, but are costlier.

Assessment by farmers

Assessment by farmers was organized around three field days, undertaken at Mafraq, Muwaqqar and Abu-Furth (Fig. 1). In addition, farmers' comments were recorded during the regular field visits and were very important in clarifying everyday problems as well as long-term difficulties or benefits of each intervention. In general, farmers were impressed by what they observed, and most of them expressed willingness to cooperate with similar projects in the future. Discussion by farmers included the following points: protection of the atriplex from grazing in the first and second year is essential; barley in the collection area would have to be cut manually during these 2 years, and not grazed directly by livestock; most farmers prefer using the local two-row variety of barley (Baladi) and not the new varieties that were used in the trial sites (Rum and ACSAD), which may produce higher yield, but were not preferred by the farmers because they consider them less palatable.

The relative merits of cultivating the collection area to barley generated much discussion. The farmers initially considered areas left without any crop (catchment area) as being a waste of land. However, the researchers explained the importance of this area in duplicating the amounts of water available for crops and the consequent increase in yield, which should compensate for the uncultivated land. The above comments were never thought about by the team of researchers, which highlighted the role of farmers in determining important aspects of the intervention details. These field days were also effective in disseminating the knowledge about these interventions, which enhances their adoption by the farmers' community. Even under different conditions, previous research indicated that field tours were a successful means of technology transfer among participants[17].

Conclusions and Recommendations

The study indicated that the suggested water-harvesting interventions are biophysically suitable and could be implemented in the study area. However, considering both socio-economic aspects and biophysical suitability is indispensable to assure successful selection and implementation of new water-harvesting interventions. Special attention should be given to the land ownership, especially the multiownership regime, which is common in Jordan. Prior to any implementation, a clear idea about these interventions should be given to all concerned owners and, consequently, their agreement and feedback are necessary to avoid any future conflict and to ensure their active participation.

Farmer's participation through regular field visits and field days is a successful tool for the dissemination of the tested interventions. Farmers showed willingness to be involved in future project activities. This participation had a crucial role in highlighting some practical problems that were overlooked by researchers. A recurrent problem for water harvesting is site protection. Unless this problem can be overcome by cheap fencing, these interventions will be difficult to maintain. The study recommended some practical alternatives to provide protection. The study also highlighted important practical and technical considerations that help in ensuring successful implementation of these interventions in the farmers' fields. Extension officers should work closely with interested farmers to provide advice about the selection, implementation and monitoring of various types of water-harvesting interventions. Farmers' needs and capabilities must form the basis for any decisions about land use. Our experience showed that successful intervention might easily fail due to small but overlooked socio-economic constraints.

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