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Predicted Willingness of Farmers to Adopt Water Harvesting Technologies: A Case Study from the Jordanian Badia (Jordan)

[1]Samia Akroush and [2]Boubaker Dhehibi

[1]Socioeconomic Studies Directorate, National Center for Agricultural Research and Extension (NCARE), Baq'a (19381). P.O.Box 639 – Amman – Jordan
[2]Social, Economics and Policy Research Program (SEPRP), International Center for Agricultural Research in the Dry Areas (ICARDA)

Abstract: Water-harvesting practices, which capture and concentrate surface runoff for crop or range production, can help to re-establish the productive functioning of Jordanian Badia environments. The main objective of this study is to assess the rate of adoption of water harvesting technologies and identify main constraints that limit the adoption process in the low rainfall areas of Jordan through using ADOPT (Adoption and Diffusion Outcome Prediction Tool). ADOPT predicts the proportion of a target population that might adopt an innovation over time. A focus group discussion (FGD) methodology was used to apply the ADOPT with group of researchers (biophysical and socio economic team) and farmers in the Middle Jordanian Badia. In the FGD we streamlined 22 discussion questions around four categories of influences on adoption: characteristics of the innovation, characteristics of the target population, relative advantage of using the innovation and Learning of the relative advantage of the innovation. The peak adoption rate for water harvesting technologies in the Jordanian Badia is predicted to be 93% after a period of 12.4 years as of using the ADOPT tool with a group of researchers working with the project. However farmers also predicted 95% after a period of 11.9 years. The results and the ADOPT tool should be of considerable assistance to policymakers in helping them develop their guidelines to facilitate the specific target group. Policymakers and extension agents will be able to distinguish between farms regarding their likelihood of technology adoption based on the prediction method.

Key words: Innovation · Adoption · Jordanian Badia Environment · Water Harvesting

INTRODUCTION

The use of new agricultural technologies has generally been found to be a function of farm and farmer characteristics and specific features of the particular technology [1-3]. A considerable set of literature has developed regarding factors that influence the adoption of new technologies by farmers through use of innovation theory [1-5].

Adoption and diffusion theory also have been widely used to identify the factors that influence an individual's decision to adopt or reject an innovation. Rogers, E. (1995) [5] defined an innovation as "…an idea, practice or object that is perceived as new by an individual or other unit of adoption. The perceived newness of the idea for the individual determines his or her reaction to it." He further identified five characteristics of an innovation that affect an individual's adoption decision:

- Relative advantage: how the innovation is better than existing technology;
- Compatibility: the degree to which an innovation is seen as consistent with existing experiences, needs and beliefs of adopters;
- Complexity: how difficult the innovation is to understand and use;
- Trialability: the degree to which the innovation may be used on a limited basis;

Corresonding Author: Samia Akroush, Socioeconomic Studies Directorate, National Center for Agricultural Research and Extension (NCARE), Baq'a (19381). P.O.Box 639 – Amman – Jordan.
Tel: (+962) (6) 4725071, Fax: (+962) (6) 4726099.

- Observability: the degree to which the results of an innovation are visible to others.

The relative advantage and observability of an innovation represents the immediate and long-term economic benefits from using it, whereas compatibility, complexity and trialability indicate the ease with which a potential adopter can learn about and use an innovation [6, 7].

As the relative advantage, compatibility, complexity, trialability and observability of rainwater harvesting techniques has caused more farmers to adopt them in arid and semi-arid areas worldwide, we can study the adoption of these technologies as an innovation. The utilization and critical mass adoption of appropriate rainwater harvesting techniques is an important prerequisite for agricultural development, particularly in Dry land areas. Against this backdrop and in the frame of the Water Livelihood Initiative (WLI) project (http:// www.icarda.org/ wli/), a study was undertaken to evaluate the factors influencing adoption of rainwater harvesting technologies.

The Badia of Jordan, the natural grazing lands, is severely degraded due to continuous grazing, cutting, plowing and severe water shortages. Rainfall is limited (100-200 mm/year) and often many factors such (as low rainfall) and uneven distribution, high losses due to evaporation and runoff and increased demand on water due to population growth decrease the available water in any case. Another problem in the Badia region is soil crust formation which reduces water infiltration. Because of the dense surface crust and the scarce vegetation cover, a large part of the rainfall runs off to the *wadis* or evaporates back to the atmosphere without any local benefit. The surface runoff also creates erosion; the floods and sediments subsequently affect maintenance costs of downstream infrastructure or reservoirs.

In arid and semi-arid areas of West Asia and North Africa, including the Badia of Jordan, farmers have been increasingly practicing more continuous barley cultivation, which is likely to be unsustainable in the long run in these areas. The objective of the study was to evaluate if barley and total dry-matter yields can be sustained by including water harvesting technique. Water-harvesting practices, which capture and concentrate surface runoff for crop or range production, can help to re-establish the productive functioning of these Badia environments. The susceptibility to degradation is common in many arid and semi-arid soils, where soil surface is characterized by low organic matter, high silt contents and low aggregate stability. Water harvesting has been used for many years in different areas all over the world to solve the problem of water scarcity in arid and semi-arid areas. Runoff farming, which includes concentrating rainfall water on a small area, effectively increases the amount of water to about 2 to 4 times the normal annual precipitation and is highly recommended for the production of many crops.

The purpose of rainwater management in an arid region includes conserving moisture in the root zone, storing water in the soil profile and harvesting excess runoff for supplemental irrigation of rainfed crops. Because only a portion of the rainwater can be stored in the soil profile, the excess runoff water needs to be harvested in on-farm structures to meet the irrigation requirements of crops and other water consuming activities in the area such as livestock watering. Because of the decline in organic matter and associated soil quality, most tillage-based farming systems in dryland environments are not sustainable in the long term. Options for maintaining and improving soil quality in the drylands are to simultaneously increase the cropping intensity and reduce or eliminate tillage. The use of spring cropping in combination with no-till sowing would appear to offer the best approach for increasing cropping intensity, improving soil quality and controlling erosion in the conventional fallow. Thus, the main objective is to assess the rate of adoption of water harvesting technologies and identifying main constraints that limit the adoption process in the low rainfall areas of Jordan through using ADOPT software.

The remainder of the paper is organized as follows. Section 2 describes the methodological framework with special emphasis on the explanation of the adoption and diffusion outcome prediction tool (ADOPT). Details of the technology characteristics and its advantages are presented in Section 3 while Section 4 discusses the main findings of this research study. Section 5 concludes with suggestions as to how to promote the adoption of this technology in Jordan.

Methodological Framework

Adoption and Diffusion Outcome Prediction Tool (ADOPT): ADOPT (Adoption and Diffusion Outcome Prediction Tool) is an MS Excel-based tool that evaluates and predicts the likely level of adoption and diffusion of specific agricultural innovations with a particular target population in mind. The tool uses expertise from multiple disciplines to make the knowledge surrounding the adoption of innovations more available, understandable and applicable to researchers, extension agents and research managers. ADOPT predicts the proportion of a target population that might adopt an innovation over time. The tool makes the issues around the adoption of innovations easy to understand. ADOPT is useful for agricultural research organizations and people interested in understanding how innovations are taken up.

The tool has been designed to:

- Predict the likely peak level of adoption of an innovation and the time taken to reach that peak.
- Encourage users to consider the factors that affect adoption at the time that projects are designed.
- Engage research, development and extension managers and practitioners by making adoptability knowledge and considerations more transparent and understandable.

ADOPT users respond to qualitative and quantitative questions for each of twenty-two variables influencing adoption. Going through this process also leads to increased knowledge about how the variables relate to each other and how they influence adoption and diffusion. ADOPT is structured around four categories of influences on adoption:

- Characteristics of the innovation
- Characteristics of the target population
- Relative advantage of using the innovation
- Learning of the relative advantage of the innovation.

Data Analysis

Target Areas and Population: Majidyya is a rural village 70 km south of Jordan's capital city of Amman. With a small population of 40 household heads and approximately 250 inhabitants, the Majidyya community members traditionally use their lands for grazing. However, continuous overgrazing has degraded the natural rangeland vegetation to an almost barren landscape. In response, some residents switched to barley cultivation. Barley is a government-subsidized crop, which typically yields little grain as a result of water scarcity, but the entire plant is used as fodder for livestock. Muharib is also a small agricultural village with 30 household heads and about 190 inhabitants. Like Majidyya, Muharib has been suffering from water shortages and degradation of arable land. Unable to earn enough in their agricultural livelihoods, some families have left Muharib for other neighboring villages or cities such as Amman where private and public services and employment provide more prospects for a better life.

Data Collection: We used a focus group discussion (FGD) methodology [8] to apply the ADOPT [9] with group of researchers (biophysical and socio economic team) whom are involved in the project activities in 2014.There were around 11 researchers who participated in the FGD. We also held a FGD with five community leaders representing Majidyya and Muharib villages at the community area during October 2014. All of them were male. Two researchers from the socio economic team at the National Center for Agricultural Research and Extension (NCARE) in Jordan and one socio economic scientist from the International Center for Agricultural Research in the Dry Areas (ICARDA: http://www.icarda.org) conducted the FGD with the farmers.

We streamlined 22 discussion questions around four categories of influences on adoption:

- Characteristics of the innovation
- Characteristics of the target population
- Relative advantage of using the innovation
- Learning of the relative advantage of the innovation.

The format of the discussion group consisted of both analytical questions (i.e., they discuss and collectively decide what they believe the answer is) and clarifying questions (i.e., questions that help clearing up confusion and explain why they had chosen this answer). Farmers were asked to think about their problems related to implementing water harvesting and the most challenging for them.

Indicators on the Target Population: Most households in the project site owned small livestock (e.g., sheep or goats). The size of the livestock herds varied from large (more than 200 heads) to small(less than 50 heads). As was the case with crop production, men were solely responsible for livestock operations particularly if it was a farm operation. Their primary responsibilities included feeding and veterinary care of the animals. Most often, their sons helped with the shearing of sheep and caring for newborn animals. Women's participation was limited to milking and dairy processing. Households hire foreign laborers to take care of the livestock, particularly to clean livestock stables and take livestock out for grazing. The majority of household's income was generated by men and did not come from agriculture. Farmers are retired from government service (i.e., army and police), or were still employed by government. A few farmers continue to generate income from farming and livestock activities. In Majidyya a social organization was available for women; a cooperative called Al-Rahmanya Association for Social Development was established in January, 2011. The cooperative consists of 60 farmers, 30 of which are women. There is also another newly established cooperative for men and women called Al Masardah.

Water is the primary concern for these WLI communities. Dilapidated artisan well infrastructures combined with the broad-scale impacts of urbanization and climate change (e.g., reduced rainfall), have increased pressure on limited water resources for household needs and for agricultural and livestock production. The water supply and management in the communities is primarily managed by the municipal authorities. Water is supplied through a central pipeline once a week which runs into a tank installed on the roof of the house. The average family (typically comprised of eight people) consumes 7-8 m3 of water in two weeks which is used primarily for cooking, cleaning, personal hygiene and laundry. The families purchase additional tanks of water (6 M^3) from water delivery trucks, which costs 20 JD per tank. This water is used to water livestock and home gardens. Households also purchase filtered water for drinking. Farmers mostly rely on rainfall to meet their crop water needs. The changes in rain patterns forced many families to switch from wheat to barley cultivation, which is planted primarily as a forage crop. Some farms have access to artesian wells though the farmers described them as poorly maintained and polluted. Some farmers indicated that they used water delivered by trucks to supplement their crop water needs when the rainfall was inadequate.

Technology Evaluation

Characteristics of the Technology (Water Harvesting Techniques): The design capacity of a water harvesting structure is normally determined by the expected value of peak runoff for the anticipated life of the structure. The peak value is determined from historical records. In practice, especially in arid regions, it may not be possible to harvest all runoff from a catchment due to various reasons. The different reasons are unavailability of suitable sites for reservoirs in adequate quantity, scarcity of roads for carriage of heavy earth moving equipment's, unwilling participation of local people, inequitable distribution of water, private ownership of land and scarcity of funds, etc. There are different types of water harvesting technologies that have been applied at the project sites; brief descriptions are summarized below.

On private ownership, The previous studies (WLI reports, Timmons, 1948) results suggested that all water harvesting practices in the Jordanian Badia were not considered to be equal by landowners. Being an owner operator or absentee owner impacted the decision to adopt or use certain types of water harvesting practices.

Timmons (1948) stressed that ownership rights translated directly into better land management measures, such as efficient land allocation and soil and water conservation. His hypothesis was that private land owners are more likely to conserve their land, compared to the public lands managed by the government agents and others, because land was a major investment that defined wealth for those private land owners. So, we can be based on this evidence to argue our statement.

Vallerani Water Harvesting: Water harvesting systems can help capture runoff flows and rebuild vegetation in degraded areas. One promising option is the Vallerani mechanized system, a special tractor-pulled plow that automatically constructs water-harvesting catchments, ideally suited for large-scale reclamation work. The Vallerani system is named after its inventor, Italian agronomist Venanzio Vallerani.

The Vallerani implement is a modified plow, pulled by a heavy-duty tractor. First, contour lines are marked on the slope. The tractor follows a contour line and the plow makes a furrow about 50 cm deep. A normal plow on flat land excavates a symmetrical furrow and earth piles up equally on both sides of the furrow. The Vallerani plow creates an angled furrow and piles up the excavated soil only on the lower (downhill) side. This soil forms a ridge that stops or slows down runoff water as it flows downhill. The plow can dig a long continuous furrow. Alternatively, as it moves forward, the plow blade can also move up and down (i.e. in and out of the soil), creating a series of small basins, each with a ridge. The size and spacing of basins will depend on the frequency of the up-and-down movement of the plow, which can be adjusted.

When a furrow or pit fills up, the overflow enters the next micro-catchment, flows into the next furrow or pit and so on. Shrubs are planted in pits along the ridges. With moisture readily available, they grow rapidly, providing livestock fodder and helping to conserve the soil. The furrows/basins also slow down runoff flows, preventing erosion. The Vallerani plow can 'treat' 30 ha in a single day, building scores of micro-catchments. For example, the 100-ha Qaryatein site (Syrian Badia) was developed in 4 days. Preparation of pits and transplantation of shrubs took another 15 days. Once the project had invested in the tractor and the plow, the remaining cost of implementation – layout, planting shrubs and training farmers to build and maintain the system – was about US$1250, i.e. about $13 per hectare. That's a small price to pay for sustainability [10].

Runoff Strips: Barley is planted in strips using a seed drill, with unplanted strips in between as catchment area. The catchment area will allow rainfall water to be harvested in the barley planted strip, which will maximize the available water for barley and as a result, the barley crop will give reasonable straw and grain yield. The ratio between the planted strip and the catchment area is suggested to be 2:2, 2:3 and 2:4 (Cultivated/catchment). However, adjustment to these ratios is made according to the width of the seed drill and to the land and soil characteristics. The planting is done as much as possible following the land contour, which require skillful driver.

Marabs: Marabs are natural formations found in the Badia where water spreads naturally over a relatively wide, slightly shallow "stream" beds and thus allow the use of this area for agricultural production (e.g., barley cultivation). Streams are ephemeral due to low rainfall and aridity and may not, in fact, exist every year.

A Marab is a water harvesting technology that is constructed at the lowest point of a watershed to collect and spread excess runoff water in order to maximize the size of land that can be brought under cultivation.

The continuous land degradation in the Badia and the relatively high rate of soil erosion decreases the effectiveness of water spreading in these Marabs. Thus, improving the ability of water to spread in these Marabs improves both the exploited area as well as the productivity of the land. For the Marabs, a bulldozer is used to scoop a deeper depression in the natural Marab, thus increasing its water holding capacity.

Advantages of the Water Harvesting Technologies: Some of the benefits of collecting and storing rainwater include:

- Diminishing flooding, erosion and the flow to storm water drain by reducing peak storm water runoff.
- Reducing water bills and demand on community's drinking water supply by using rainwater for flushing toilets, washing clothes, watering the garden.
- Improving plant growth (barley and rangeland shrubs) by using rainwater for irrigation because stored rainwater is free from pollutants as well as salts, minerals and other natural and man-made contaminants.
- Making use of a valuable resource that is free.
- Recharging the ground water and the source of water for livestock watering

RESULTS AND DISCUSSION

The innovations being discussed included various water harvesting systems; the most expensive of these is to build contour ridges with a Vallerani machine. Other systems include improved Marabs (requiring a bulldozer and engineering assistance to calculate slopes), cisterns and water harvesting using runoff strips for rangeland shrub and barley growth, which have been studied over many years in the Jordanian Badia. The results of the program predicted that 93% of the communities would adopt the innovations after 12.4 years. The program was applied in 2014 with the group of farmers and researcher. The breakdown of the questions and the reasons for their answers are discussed below.

Learnability of the Population[1]: Learnability of the population concerns the characteristics of the population that affect their ability to learn about the innovation. There are four questions regarding this aspect of adoption, which focus on group involvement in the community relevant to the innovation, whether or not the populations uses advisors to get relevant advice about the innovation, the relevant existing skills or knowledge in the population and the awareness of the innovation in the population.

- What proportion of the target population uses paid advisors capable of providing advice relevant to the innovation?—Almost none use a relevant advisor.

[1]All information concerning how ADOPT works was found at: http://aciar.gov.au/files/node/13992/adopt_a_tool_for_evaluating_adoptability_of_agric_94588.pdf.

Explanation: Most farmers do not pay for advisory support for farming, in part because it is usually offered for free in the Badia (a combination of researchers such as ICARDA and governmental researchers working in the area). The researchers agreed that the farmers in the Badia would be unwilling to pay for such advice and one of the researchers commented that it is more common for farmers in irrigated areas to pay for advisory support. The researchers also noted that farmers in the Badia will pay for nutritional and veterinary advice for their livestock.

- What proportion of the target population participates in farmer-based groups that discuss farming?—A minority (10 % of target population) are involved with a group that discusses farming.

Explanation: There is only one community based organization (CBO) in the studied area and it is not considered active. The researchers also mentioned that the majority of the farmers live far from the population center, possibly making cooperation difficult. When asked about farmers' attendance to ICARDA-run field days, the researchers commented that there is a much higher turn out to field days when they are held on the weekend, although the field days are usually held during the week.

- What proportion of the target population will need to develop substantial new skills and knowledge to use the innovation?— A minority will need new skills and knowledge.

Explanation: Cisterns have been in use for so long that the majority(More than 60%) of farmers understand their use and would be willing to utilize them. Though the Vallerani machines have been around the studied area for less time than cisterns, they have been used for enough time now that the majority of farmers are also familiar with them. Improving the Marabs using bulldozers is the newest technique, but the practice is fairly simple. Some researchers have noticed that a few farmers not involved with the testing have begun digging Marabs on their land, meaning that they were able to understand and adopt the technology without the help of any researchers. However, the researchers again emphasized the overall lack of understanding about environmental conservation among the farmers, which would make it difficult to persuade farmers to implement techniques that have environmental benefits but no immediate financial benefits to the farmers.

- What proportion of the target population would be aware of the use or trialing (trying) of the innovation in their district?— About half are aware that it has been used or trialed in their district

Explanation: Other experiments were previously conducted in the current research area, giving many of the farmer's exposure to the concept of water harvesting. Some farmers were familiar with cistern use before trials began. Additionally, the majority of the techniques are highly visible, meaning that a large portion of the farmers are aware of the testing in their area.

Learnability of the Innovation: Learnability of the innovation refers to the characteristics of the innovation itself that determine a group's ability to learn about it. Three factors are used to determine this aspect of the adoption process: the ability to run small trials of the innovation, whether or not the innovation requires complex changes to the farmland for implementation and the level of observation of the innovation.

- How easily can the innovation (or significant components of it) be tried on a limited basis before a decision is made to adopt it on a larger scale?— Very easily trialable.

Explanation: The techniques can be applied at a small scale and it is possible to generate results in one season.

- Does the complexity of the innovation allow the effects of its use to be easily evaluated when it is used?— Not at all difficult to evaluate effects of use because it is not complex

Explanation: The effects of the technology are easy to ascertain at the sites in which they were used, that is, on a small level. On a larger scale, both implementation of the technology and understanding of its effects become more difficult.

- To what extent would the innovation be observable to farmers who are yet to adopt it when it is used in their district?— Very easily observable

Explanation: Most of the technologies involve physically shaping and re-forming the ground, which makes them visible even from a car driving by the test site.

Relative Advantage for the Population: Relative advantage for the population attempts to determine whether the advantage that the population could gain from the innovation is sufficient to encourage the population to adopt the innovation. To assess this aspect, the program asks six questions which review the following: the number of farmers that could benefit from the innovation, the extent to which farmers use long-term planning, how much the farmers' decisions are motivated by maximizing profits, how much the farmers' decisions are motivated by protecting the environment, the community's level of risk aversion and short-term financial restraints.

- What proportion of the target population has maximizing profit as a strong motivation?— About half have maximizing profit as a motivation

Explanation: Some of the techniques, such as water harvesting for shrubs need up to four years before they will give a profit increase to the farmer and even then the increase is modest. Using the Vallerani machines to construct contours ridges has more of a visible impact on shrub production, but the machines have a high initial investment rate. In contrast, improving the Marabs has a very rapid and large impact on barley production, making it possible that financial reasoning is a more important motivating factor in increasing use of the technology on the Marabs.

- What proportion of the target population has protecting the natural environment as a strong motivation?— A minority have protection of the environment as a strong motivation

Explanation: The farmers continue to practice unsustainable ploughing techniques and the researchers say that farmers' care more about being able to make a profit this year than implementing new and possibly more complicated techniques. The researchers do not believe that the farmers have a good understanding of the conservation reasons behind the techniques being developed and are not aware of the environmental benefits of applying such technologies.

- What proportion of the target population has risk minimization as a strong motivation?— A majority have risk minimization as a strong motivation.

Explanation: Crop production and farmers' incomes with it decrease during drought years, meaning that drought can have a large effect on farmers' lives. They are therefore very concerned about drought and other risks to their farms.

- On what proportion of the target farms is there a major enterprise that could benefit from the innovation?—About half of the target farms have enterprises that could benefit from the innovation.

Explanation: A majority of farmers have an integrated livestock (mostly goats) and crop system. The water harvesting techniques can create increased livestock fodder, giving farmers a noticeable benefit during drought years.

- What proportion of the target population has a long-term (greater than 10 years) management horizon for their farm?—A minority have a long-term management horizon

Explanation: The researchers believe that the farmers do very little long-term planning on their farms. The only long-term planning that the researchers were able to point out was the occasional planting of olive trees. However, it is certainly a minority of farmers that has done so. Additionally, the researchers pointed to the fact that there are laws regarding not planting rangelands to allow for re-growth of vegetation. However, during rainy years the farmers will farm the rangelands in order to make a profit, thereby disregarding the long-term plan for recovery. Other potential reasons for the lack of long-term management could be the very high initial investment rate for long-term plans such as planting olive trees, coupled with the high risk-if there is a drought during the trees' early years, they will die and the farmers will lose their entire investment. Furthermore, instances of drought have increased in recent years, leading farmers to believe that they are increasingly likely to lose profit to drought. Some of the researchers also pointed out that the soil in the studied areas is not very good for olive trees, which might affect farmers' decisions to plant trees. But, there was uncertainty amongst the researchers as to whether or not the quality of the soil would actually affect tree growth and whether or not the farmers knew or understood the effect of the soil quality.

- What proportion of the target population is under conditions of severe short-term financial constraints?—About half currently have a severe short-term financial constraint.

Explanation: Land and livestock in Jordan are quite expensive, meaning that farmers that own their own land or that own livestock have significant financial assets. However, there was uncertainty among the researchers about the farmers' ability to access liquid money. Some of the researchers believed that several farmers have quite a lot of financial resources, but the majority of the researchers believed that those with access to cash were only outliers and that the majority of farmers have very little available cash.

Relative Advantage of the Innovation: Relative Advantage of the Innovation looks at the objective advantages of the innovation without considering the community's perception of the innovation. This part of the process is assessed through eight questions, which deal with the following: the initial costs of implementation, whether or not implementation can be reversed to allow for other innovation options, overall change in profit to the farms from the innovation, how long it will take for the change in profit to take effect, whether or not the innovation decreases farmers' vulnerability to seasons with difficult conditions, the advantages and disadvantages to the environment as a result of implementation, how long until the environmental effects are noticeable and the non-monetary benefits of the innovation to the farmer.

- What is the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation?— Very large initial investment.

Explanation: The amount of initial investment varies depending on the technology, but the researchers noted that using the Vallerani machine to create contour ridges, in particular, requires a very large initial investment. The newer version of the Vallerani tractor has a larger motor, meaning the investment for the machines is up to 200,000 JD (132,000JD for the tractor alone). The researchers also commented that farmers would be unlikely to buy a piece of equipment that is used for only one task. There has been discussion of organizing a rental system in which one Vallerani machine would be rented out to multiple farmers for a low cost of use plus the fuel for the tractor, but no such system is currently in place.

- To what extent is the adoption of the innovation outputs able to be reversed?— Easily reversed

Explanation: The studied area is already subject to high levels of land deterioration and soil erosion, so if the technologies are not maintained, the land will return to its former state in three to four years and if the vallerani machine is not available the system will revert.

- To what extent is the use of the innovation likely to affect the profitability of the farm business in the years that it is used?— Moderate profit advantage in years that it is used.

Explanation: The profit gained from these technologies is highly dependent on the amount of rainfall each year. Marabs and cisterns in particular have a high profit impact in years with an average amount of rainfall, but during drought years there will be little impact.

- To what extent is the use of the innovation likely to have additional effects on the future profitability of the farm business?— Moderate profit advantage in the future

Explanation: The future profit advantages will likely be felt most strongly after a generation, after the technologies have had time to work their more far reaching effects, such as stopping soil erosion and encouraging more plant growth.

- How long after the innovation is first adopted would it take for effects on future profitability to be realized?— 3-5 years.

Explanation: The effects of cisterns and Marabs can be felt in as short as 1-2 years, although the benefits of the Marabs will continue to increase for the first few years of their use as plant matter accumulates and makes the ground more fertile. Water harvesting techniques used to grow shrubs need around four years before the shrubs can be used as fodder for livestock.

- To what extent would the use of the innovation have net environmental benefits or costs?— Large environmental advantage.

Explanation: The technologies create soil and water conservation, concentrate organic matter in the soil and allow for natural regeneration of vegetation, which is considered to be a large environmental advantage. In a communal grazing system such as the Badia, however, keeping livestock off the shrubs until they are mature enough to use will remain a constant issue.

- How long after the innovation is first adopted would it take for the expected environmental benefits or costs to be realized?—More than 10 years.

Explanation: The greater environmental effects such as increasing water table and soil conservation will accumulate over time and therefore need at least ten years before they will be fully felt barring any additional deleterious climate change effects.

- To what extent would the use of the innovation affect the net exposure of the farm business to risk?— Large reduction in risk.

Explanation: Once the deeper environmental effects are felt, the water captured in the soil profile will enable production of more livestock fodder. Cisterns enable farmers to take less water from the ground, meaning that the system will be healthier and less susceptible to damages from heavy drought years.

- To what extent would the use of the innovation affect the ease and convenience of the management of the farm in the years that it is used?— Moderate increase in ease and convenience.

Explanation: The convenience levels of the technologies vary. Cistern use means that farmers no longer have to hire trucks to bring them water over long distances, which is more convenient. However, in techniques used to increase shrub growth in rangelands, the farmers do not like following the grazing restrictions and keeping their livestock contained.

As mentioned above, the peak adoption rate for water harvesting technologies in the Jordanian Badia is predicted to be 93% after a period of 12.4 years (Figure 1). According to factors such as farmers' profit, environmental and risk orientations, the number of farmers expected to benefit from the innovations, the environmental and profit advantages, the ease and convenience of implementation and use and the risk and investment costs, the relative advantage—and therefore the level of peak adoption—of the innovations is quite high. According to the Figure 2 which explain the sensitivity analysis for the main factors affecting the adoption level and peak, it appears that farmers skills and networks, the trialability of the innovations, combined with the relative advantage of the innovations make up the population's ability to learn about the innovations and this combined with the factor of short-term financial constraints determines the time to peak adoption.

The results of the Focus group with farmers showed that the peak adoption rate for water harvesting technologies in the Jordanian Badia is predicted to be 95% after a period of 11.9 years (Figure 3). According to factors such as farmers' profit, environmental and risk orientations, the number of farmers expected to benefit from the innovations, the environmental and profit advantages, the ease and convenience of implementation and use and the risk and investment costs, the relative advantage—and therefore the level of peak adoption—of the innovations is quite high. According to the sensitivity analysis results presented in the Figure 4, there are number of factors that influence the level and the time to peak of adoption of technology such as the size of the up-front cost of the investment relative to the potential annual benefit from using the innovation, the proportion of the target population need to develop substantial new skills and knowledge to use the innovation the easiness of the innovation (or significant components of it) to be trialled on a limited basis before a decision is made to adopt it on a larger scale and of the short-term financial constraints.

Concluding Remarks and Policy Implications: Water-harvesting practices, which capture and concentrate surface runoff for crops or shrubs, can help to re-establish the productive functioning of degraded Badia environments. The farmers' skills and networks, the trialability of the innovations, combined with the relative advantage of the innovations make up the population's ability to learn about the innovations and this combined with the factor of short-term financial constraints determines the time to peak adoption.

The adoption of such technologies offers an opportunity for arresting and reversing the downward spiral of resource degradation, decreasing cultivation costs and making agriculture more resource – use-efficient and sustainable in the Jordanian Badia. Therefore, results also show that rangeland improvement is possible via the implementation and adoption of the said technologies but only if the use of these technologies is combined with strict attention given to the access rules of grazing in rangeland by the policy makers, researchers and different institutions. Though farmers perceived technology as good thing to them, they still faced problems in application of technologies.

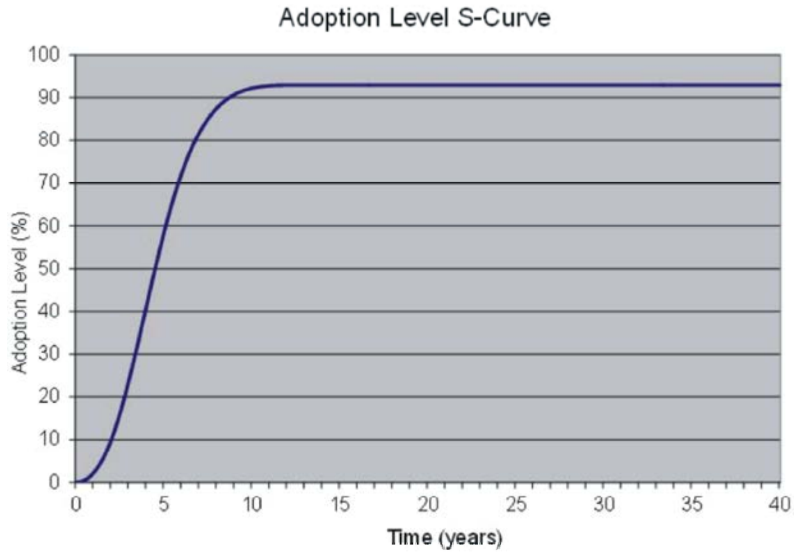

Fig. 1: Predicted Adoption Curve (Interviewed with project Researchers)
Source: Own elaboration from ADOPT

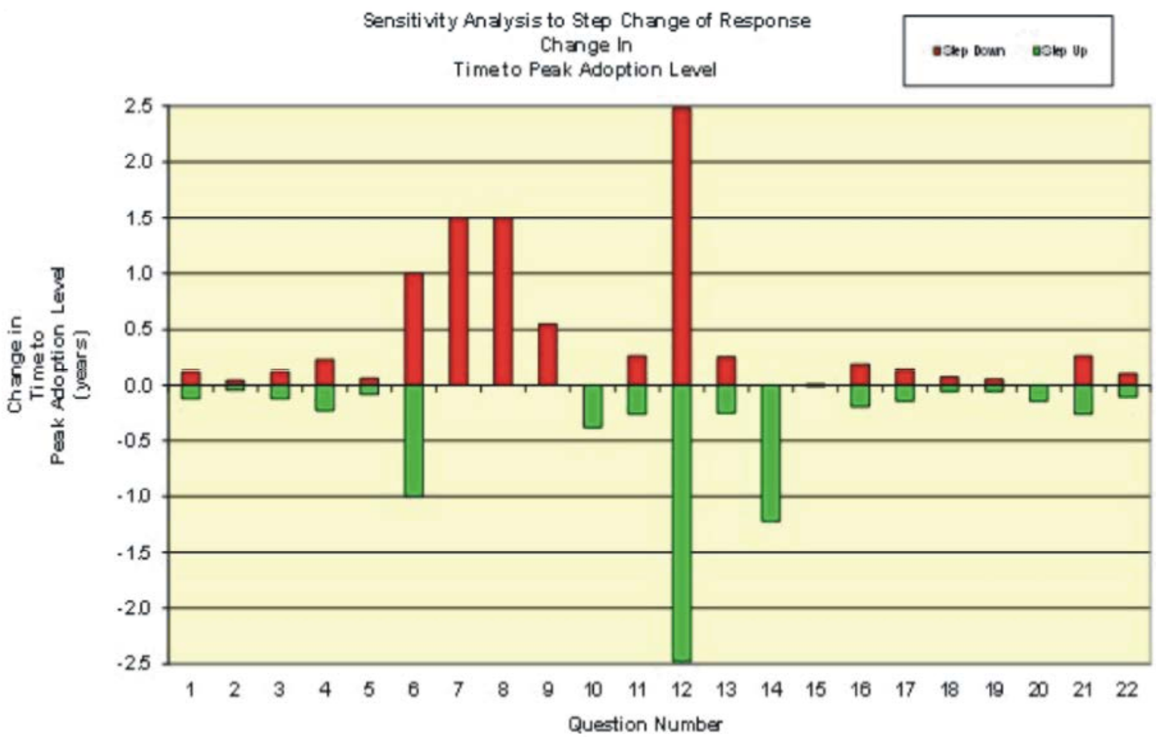

Fig. 2: Sensitivity Analysis of adoption curve (Interviewed with project Researchers)
Source: Own elaboration from ADOPT.

Enhancing the establishment of rangelands users association or cooperatives and a real involvement of rural communities in the collective action of rangeland management could be a practical solution to improve rangeland in the Jordanian Badia and make benefit of it in a sustainable manner. Finally, the introduction of targeted incentives within a new and institutional incentive structures combined with a participatory approach mechanism of local communities during the planning and implementation processes of these technologies will not generate adverse effects on its adoption.

Fig. 3: Predicted Adoption Curve (Interviewed with farmers)
Source: Own elaboration from ADOPT

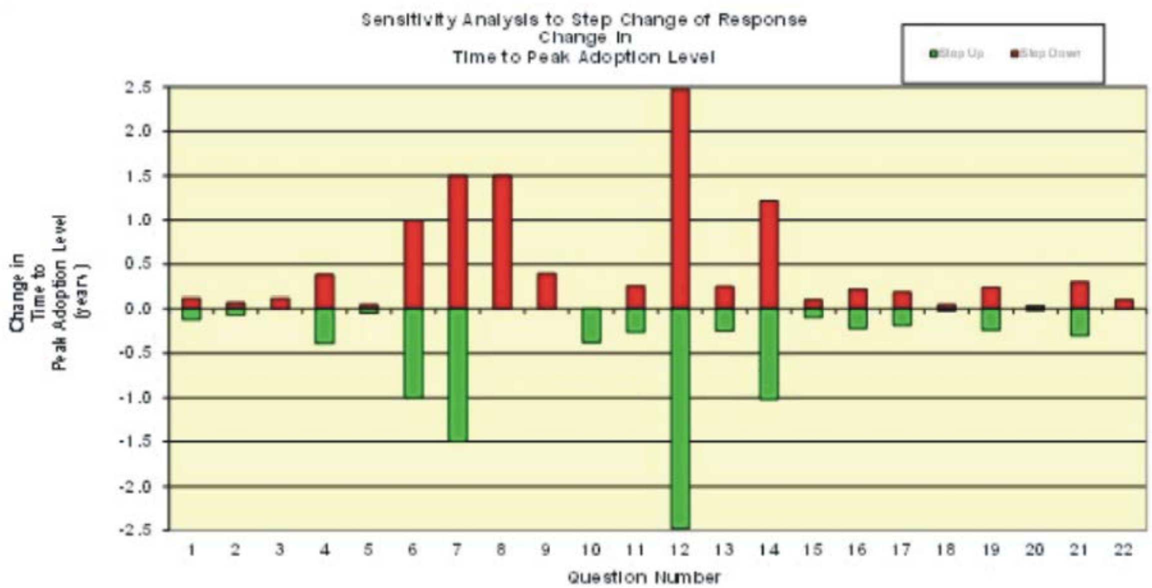

Fig. 4: Sensitivity Analysis of adoption curve (Interviewed with farmers)
Source: Own elaboration from ADOPT

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