Adoption and Impact Assessment of Improved Technologies in Crop and Livestock Production Systems in the WANA Region

The Development of Integrated Crop/Livestock Production in
Low Rainfall Areas of Mashreq and Maghreb Regions
(Mashreq/Maghreb Project)

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Foreword

The low rainfall areas (200–350mm) of West Asia and North Africa (WANA) region are characterized by low levels of economic activity, high incidence of land degradation, and a high concentration of rural population. Agriculture accounts for nearly 30% of the total labor force in the region. Adoption rates of improved technologies are very low due to low public and private sector investment in agricultural research and technology transfer. This, coupled with increased incidences of drought, has resulted in increased poverty and hardship among small producers of rural populations. More than 38 million of the total WANA population live in rural areas, and depend mainly on farming for their livelihoods.

Crop-livestock systems are the predominant enterprise, with major household income generated from small ruminant production. Livestock feed on extensive rangeland during winter and spring, and are moved to cultivated areas for grazing of cereal stubbles and other crop residues in summer and fall. The contribution of native rangeland to animal feed requirements has decreased from 70% five decades ago to no more than 25% at present. This is due mainly to increased number of animals and the demand for their products.

Inappropriate land use policies and the absence of secure property rights have often contributed to unsustainable use of land and rangeland resources. Land degradation resulting from the loss of vegetation through overgrazing, ploughing and fuel wood extraction, and consequent soil erosion via wind and water, is also common in WANA countries. This problem is exacerbated by land ownership and tenure issues, where land is collectively owned by the public.

To address these challenges, therefore, the Mashreq/Maghreb (M&M) project was initiated and designed as an adaptive research program for the development of integrated crop-livestock production systems in the low rainfall areas of WANA. The M&M project has succeeded in developing and disseminating several technological options, among which are improved barley varieties, introduction of forage legumes into barley rotation, fodder shrubs (*Atriplex* and cactus), improved rams, feed blocks, and other flock management practices.

This publication documents the empirical results of uptake by end-users, constraints to adoption, and impact of the technologies. The results have important research and policy implications toward increased investment in the dry areas of WANA region. I therefore recommend it to the major players in agricultural development in WANA region, including students of agriculture, researchers, policymakers, the general public, and most especially governments of the WANA countries.

We are grateful to the following institutions for providing financial support for the project: International Fund for Agricultural Development (IFAD), the Arab Fund for Economic and Social Development (AFESD), the International Development Research Center (IDRC), the Ford Foundation, the CGIAR System-wide Program on Property Rights and Collective Action (CAPRi), and the Forum Euro-Mediterranean des Institute Economiques (FEMISE). We also appreciate the efforts of the researchers who collaborated on the project.

Prof. Dr Adel El-Beltagy
Director General

Introduction

The Mashreq/Maghreb Project

The Mashreq/Maghreb (M&M) Project was designed as an adaptive research program for the development of integrated crop-livestock production systems in the low rainfall areas of West Asia and North Africa (WANA). It was established in 1995 with the main objective of developing more productive and sustainable small ruminant systems through the integration of crop and livestock production within and across the barley and rangeland-based systems of Iraq, Lebanon, Jordan, Syria – Mashreq – and Algeria, Libya, Morocco and Tunisia –Maghreb.

The project evolved from a technology component-testing program to one of integrated adaptive research that addressed technical, socioeconomic, cultural, institutional, and policy options issues for communities in the dry areas. Expected outcomes included improved income and welfare of farmers and pastoralists, increased production to meet the demands for small ruminant products, and improved conservation of the natural resource base. Successful technologies included improved barley varieties, multinutrient feed blocks, forage legume-barley rotations, multipurpose cactus and shrubs, improved sheep fertility and reproduction, and the rehabilitation of degraded rangelands.

The Mashreq/Maghreb (M&M) Project was initiated and designed as an adaptive research program for the development of integrated crop-livestock production systems in the low rainfall areas of WANA. During the first phase of the project (1995–1998), participatory approaches were used with individual farmers and through farmer-managed field trials of technology components. During the second phase (1999–2002), the approach evolved into an integrated natural resource management (INRM) approach. The initial entry points were the technologies that addressed the constraints of limited feed resources and increasing land degradation. Technological, institutional and policy options were developed by a multidisciplinary and multi-institution team consisting of two CGIAR centers (ICARDA and IFPRI); the national teams of Algeria, Iraq, Jordan, Lebanon, Libya, Morocco, Syria, and Tunisia; and two rural communities from each of the eight participating countries.

The M&M Project was supported by the International Fund for Agricultural Development (IFAD), the Arab Fund for Economic and Social Development (AFESD), the International Development Research Center (IDRC), the Ford Foundation, the CGIAR System-wide Program on Property Rights and Collective Action (CAPRi), and the Forum Euro-Mediterranean des Institute Economiques (FEMISE).

Study Background

Technology is the most important force in increasing agricultural productivity in the long-term. However, to affect productivity, technology must be adopted in the production processes. Largely, the rate of adoption of a new technology is subject to its profitability, degree of risk associated with it, capital requirements, agricultural policies, and socioeconomic characteristics of farmers.

New technology adoption is an important source of productivity gains in various production systems. Producers benefit from the adoption of new technology through opportunities to lower their production costs, either by increasing outputs from the same inputs or by maintaining the same output from reduced inputs.

One of the short-term impacts of a new agricultural technology is an increase in the incomes of farmers adopting the technology. However, the most important aspect is the effect of the technology on the pattern of income distribution among farmers. Previous studies have attempted to measure farm income inequality and to isolate and measure the net effect of new technology on farm income distribution. The issue here is the tradeoff between more income and an equal distribution of income.

New technology may change the optimal levels of inputs, but the profitability of adopting new technology depends on how the demands for inputs are changed and how large the productivity improvement is. Thus, an understanding of the effect of new technologies on productivity is crucial for a better understanding of the potential diffusion of the technology among farmers.

Widespread adoption of new production technology is expected to have important market-level effects. This means that widespread adoption of a new technology is likely to have economic implications beyond the production system. Thus, an integrated economic model incorporating both production and marketing systems is required to assess accurately its impacts. Farm-level models are necessary to establish the output and revenue changes from the technology. Market supply responses can then be estimated by aggregating the farm responses under an assumed adoption rate.

The Mashreq/Maghreb project has introduced several crop and sheep improved technologies into the farming system of Algeria, Iraq, Jordan, Lebanon, Libya, Morocco, Syria, and Tunisia. With the impressive adoption rates of these technologies as it was evident from technology adoption surveys, the M&M project has contributed to the welfare of farmers in WANA region. Thus, there is a need to quantify the impact of new technologies at the farm, community, and national levels.

The main purpose of this document is to present the results of several case studies related to the adoption and impact of the introduced technologies. This required harmonization and unification of methodologies, procedures and data collection to facilitate comparative analyses across participating countries. Three regional and sub-regional workshops were held to achieve this purpose. The first regional workshop was held in Baghdad on 18–21 March 2001 with the main thrusts of developing performance indicators for all project activities and adopting appropriate methodologies for assessing adoption and impact studies. The other two workshops were sub-regional and were held in Baghdad and Tunisia on 21–30 March and 15–22 May 2002 respectively. The focus of those two sub-regional workshops was to quantify adoption indicators and economic impact of introduced crop and livestock technologies in Mashreq and Maghreb countries.

This report is in three main parts. The first includes the theoretical framework underlying adoption and impact assessment of improved technologies. It also includes the relevant methodologies. The second part is a synthesis of the results obtained from the case studies conducted in the eight countries. The third part includes detailed country working papers for adoption and impact studies. The results clearly demonstrate wide adoption of the introduced technologies and their economic feasibility in improving the welfare of rural communities in WANA region. They further support the effectiveness of the technology transfer mechanism adopted by the Mashreq/Maghreb Project.

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Theoretical Framework for Assessing Adoption and Impact of Improved Technologies

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The Farm and Nature of Technological Change

Technological improvement has two general properties. The first is the development of a new production function such that a greater output is achieved from a given input level. Figure 1.1 depicts this process. Production function I represents technological change, while production function II represents old technology. With the same input level, OX, output is increased from OE to OF because of the shift in the production function due to the new technology.

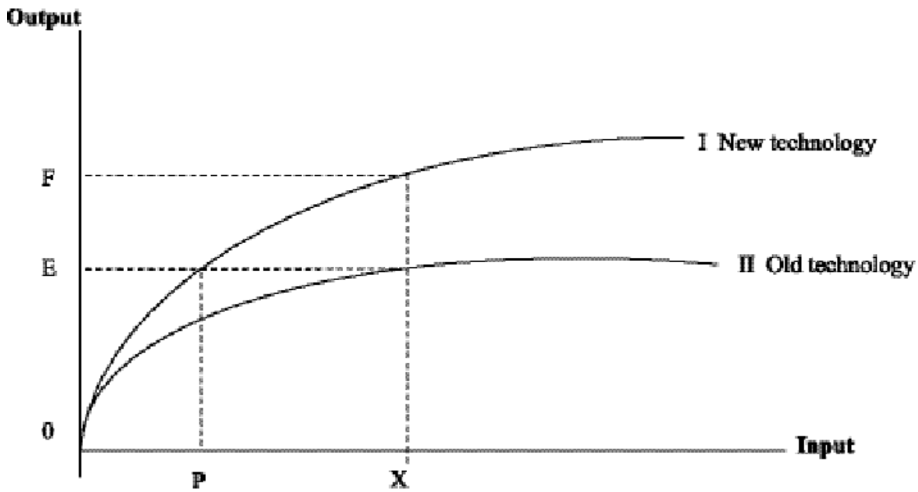

Figure 1.1 **The nature of technological change**

Alternatively the same output level, E, can be produced with a lower level of input (OP), due to the introduction of the new technology.

The second property is that the technological improvement must monetarily increase the discounted profits (or decrease losses) of the firm. The firm would never adopt an innovation if output were not increased from given resources, or if input decreased for a given output (Heady, 1952). In other words, the firm's cost curve must be lowered. The only exception would be the case in which the innovation increased *ex-ante* profit expectations through risk reduction. Even then, the long-term and aggregate effect is likely to be output-increasing .

In a purely physical and farm sense, it is possible for an innovation to be factor-saving, factor using, or output-increasing. Technological change may also combine factor-using or factor-saving with output-increasing features. The largest proportion of technical innovations in agriculture has been output-increasing. They have even lowered the average unit cost of farm products and of a factor-using nature in the sense that the lower marginal costs have caused farm firms to use more resources (Heady, 1952).

The on-farm benefits of agricultural research or extension often depend on the way the new technology or information affects the farming system. Given the difficulty and complexity of accurate benefit estimation, there is a renewed role for farm-level economic models (such as whole-farm linear programming models) in this area.

In applying benefit-cost analysis to research, different types of information are needed. For farm level research, the estimation of on-farm benefits is notable for being critical to analysis and difficult to obtain accurately. Handling of this very complex issue has often been oversimplified. Pannell (1999) outlines the risks of simplified approaches to estimation of farm level benefits of research and to raising awareness of the utility of relatively detailed farm models in research evaluation.

Most research administrators are motivated to support economic evaluations in order to obtain evidence that will support the cases they make externally to maintain current levels of funding in the face of threatened cuts. They also would want to help prioritize research to identify low-return areas for cuts and high-return areas and new opportunities for increased funding.

The Difficulty of Estimating On-farm Benefits of Research

Evaluation of an agricultural research project using benefit-cost analysis requires the following information components (Pannell, 1999):

- Predicted (*ex ante*) or estimated (*ex post*) biological, technical and/or management changes from research outcomes.
- Any negative or positive side effects (internal or external to the farm) resulting from conducting the research. This would include any environmental externalities and price impacts from changes in supply or demand.
- Costs to the farm firm of implementing findings from the research.
- Given (1), (2) and (3), the potential economic benefits per hectare or per farm (net of costs to the farm firm but not of research costs).
- The scale of potential benefits: the number of hectares or farms potentially affected.
- Proportion of the potential scale with which adoption occurs, and the timing of the adoption.

- Probabilities of different levels of success from the research.
- Direct costs of undertaking the research over time.
- The discount rates.

In practice, the outcomes of benefit-cost analyses of research are most sensitive to items (4), (5) and (6). Of these, the scale of potential benefits can be estimated with tolerable accuracy, but substantial uncertainty often surrounds farm level benefits and adoption.

Figure 1.2 depicts the time path of the return to investment in agricultural research (new technology). Investment in time (t) produces an expected stream beginning in year t+3 and rising to the level m by year t+10. Since technology is subject to depreciation, it is possible that gains once realized will be lost. The decline after year t+10 reflects this possibility.

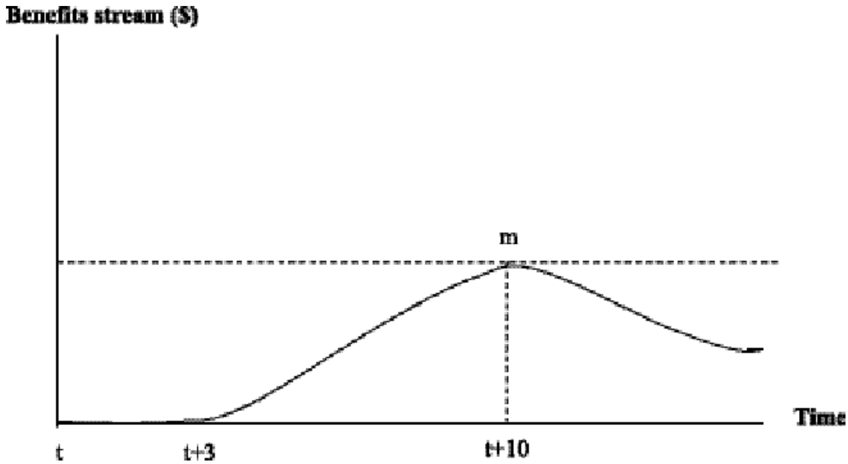

Figure 1.2 **Time path of research benefits**
(Robert E. Evenson, undated)

Effect of New Germplasm on Yield Increase

The nature of the impact of a new variety is important to the form of the analysis to be used. The variety can lead to a permanent shift to a higher yield potential trend line (A in Figure 1.3), or the gain can be a "one-off" increase that is eroded over time (B in Figure 1.3).

The analysis used in previous studies is based on the proposition that the new varieties have led to a permanent upward shift in yield potential over what would have occurred otherwise (that is, A rather than B in Figure 1.3). If this is the case, the important question is the size of that upward shift in yield potential.

A genetic improvement in yield means an increase in productivity, in a sense that there is higher output for each level of input. In economic terms, the yield increasing effects of a new variety result in a shift of the supply curve. Following Brennan and Fox (1995), increase in productivity is defined as a parallel vertical shift in the supply curve through a lowering of the production costs per tone (Figure 1.4).

Economic Surplus Methods

The concept of economic surplus underlies most of the methods used by economists to estimate the benefits and costs of agricultural research, or to assess agricultural research priorities. This basic economic surplus approach can be varied to model and measure the economic effects of research – indicated technical changes in the market settings that confront researchers.

Figure 1.5 shows the basic model of research benefits in a closed economy. D represents the demand for a homogeneous product, and S_0 and S_1 represent, respectively, the supply of the product before and after a research-induced technical change. The initial equilibrium price and quantity are P_0 and Q_0, but after the supply shift they are P_1 and Q_1.

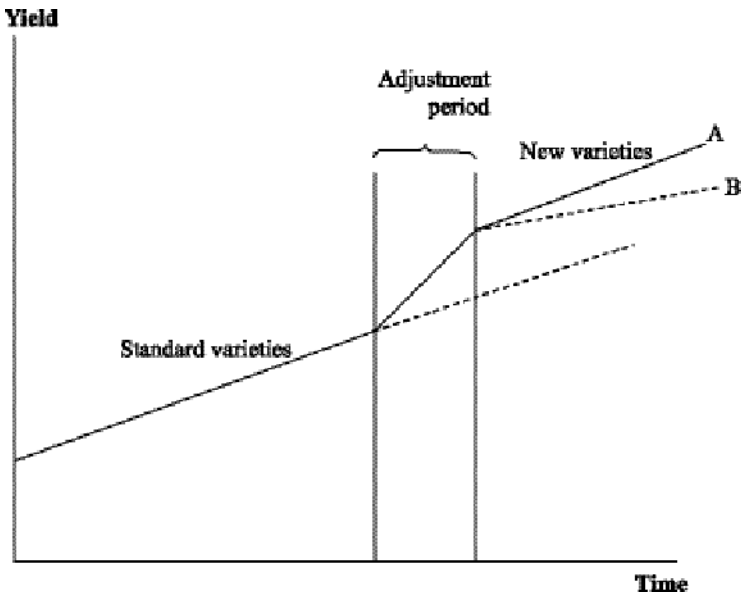

Figure 1.3 **Effect of new germplasm on rate of yield increase**

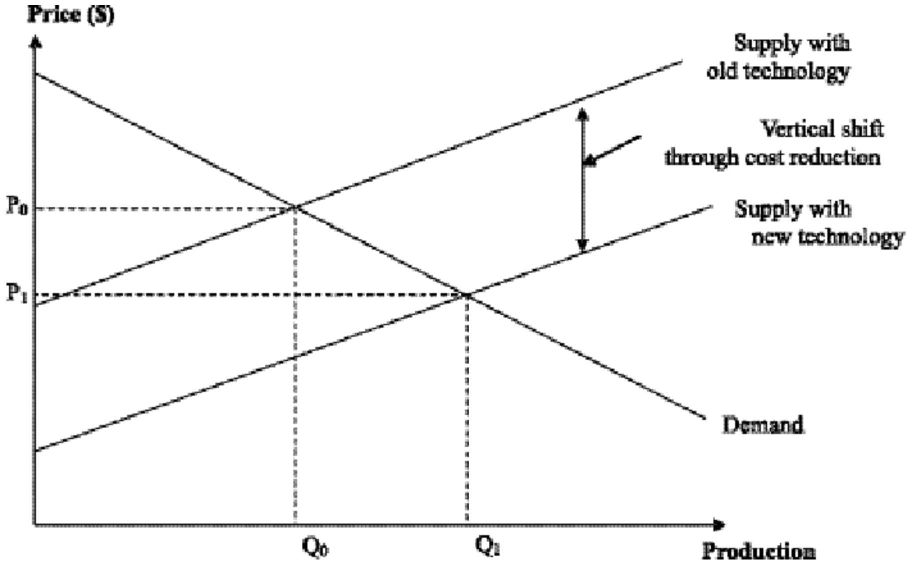

Figure 1.4 **Shift in supply curve**

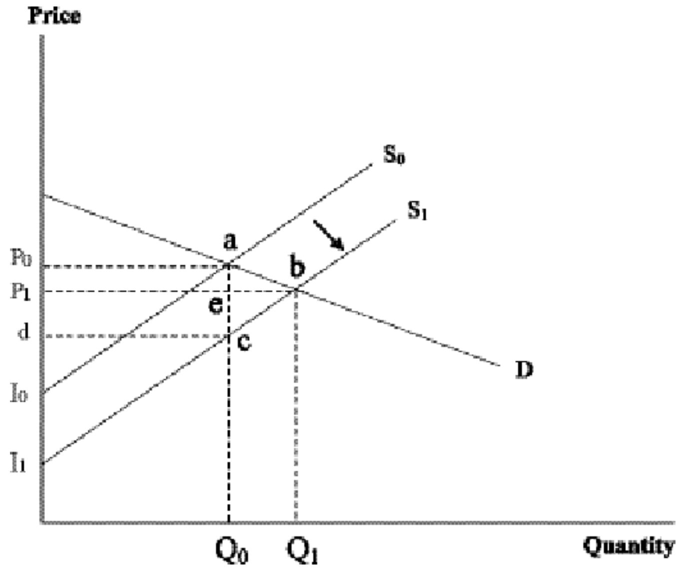

Figure 1.5 **Surplus distribution in the basic model of research benefits** (Alston, Norton and Pardey, 1995)

The total annual benefit from the research-induced supply shift is equal to the area beneath the demand curve and between the two supply curves (ΔTS = area I_0 abI_1). This area can be viewed as the sum of benefits to consumers in the form of a change in consumer surplus (ΔCS = area P_0 abP_1), and benefits to producers in the form of the change in producer surplus (ΔPs = area P_1bI_1 minus area P_0 a I_0). Under the special assumption of a parallel supply shift, where the vertical differences between the two curves is constant, area dcI_1 = area P_0 a I_0 and the change in producer surplus is equal to the net benefit on current production (area P_1 ecd) plus the gain on the increment to production from Q_0 to Q_1 (area bce) for a total producer surplus gain of area P_1 bcd.

These effects can be expressed algebraically as follows (Alston, Norton and Pardey, 1995):

$$\Delta CS = P_0\, Q_0\, Z\, (1 + 0.5\, \eta)$$
$$\Delta PS = P_0\, Q_0\, (K - Z)\, (1 + 0.5\, Z\eta)$$
$$\Delta TS = \Delta CS + \Delta PS = P_0\, Q_0\, K\, (1 + 0.5\, Z\eta)$$

Where:
k = the vertical shift of the supply function expressed as a proportion of the initial price
η = the absolute value of the elasticity of demand
$\in$ = the elasticity of supply
$Z = K\in/(\in + \eta)$ is the reduction in price, relative to its initial (pre-research) value, due to the supply shift.

Impact of Technology on Income Distribution

Another widely used method of representing distributions in economics is the Lorenz curve (Figure 1.6). This curve is useful for indicating the degree of inequality in the distribution income and other factors among farmers, households, etc. In the example in Figure 1.6 the cumulative proportion of farm population is plotted on the horizontal axis (ordered from smallest to largest), and the cumulative proportion of the total income is plotted on the left-hand vertical axis (thereby determining the calibration on the right-hand vertical axis). If the distribution were totally equitable, with each farm being of the same income, the distribution would fall on the 45-degree line. Because the distribution of income is inequitable between farmers, the actual curve falls below this line. Moreover, the greater the inequality, the greater the departure from the 45-degree line. The ratio of the total area under the 45-degree line is a measure of inequality, known as the Gini coefficient. Gini coefficients greater than about 0.35 are usually regarded as high (Dillon and Hardaker, 1993).

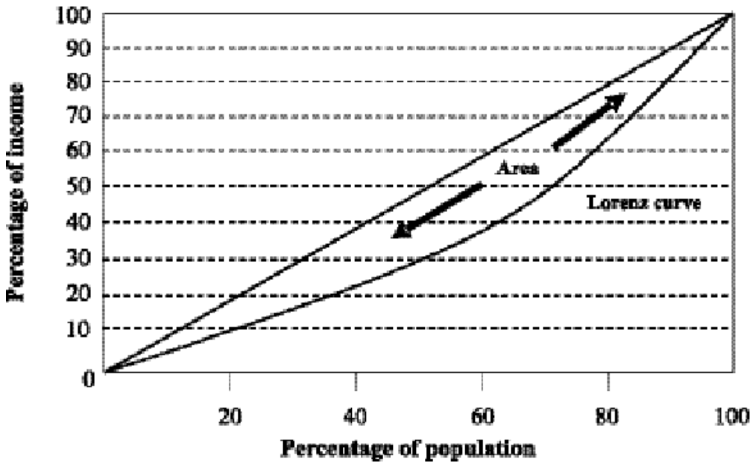

Figure 1.6 **Measuring the degree of income inequality**

Poverty Status

To assess the poverty status prevailing in the selected communities, a Gini coefficient can be estimated using information collected from the household survey. The Gini coefficient has been widely used in previous research to assess the relationships between income inequality and income level. It is derived from the Lorenz curve, where the cumulative percentage of household income distribution is drawn on the vertical axis and corresponds to the cumulative distribution of the number of households on the horizontal axis.

While the Gini coefficient measures the degree of income inequality, it provides very little information on the factors that determine it and cause it to change. Yet, income inequality is one of the major contributing factors to poverty and food insecurity. The Gini coefficient ranges from 0 to 1, with 1 indicating perfect income inequality.

The cross-community income distribution obtained from the household survey can be used to calculate the Gini index for each community, using the following formula (USDA, 1997):

$$GC = [2x \, Cov \, (Y_t, F(Y))/Y]$$

where GC = Gini index of income inequality
Y_t = mean income in the quintile
F(Y) = cumulative distribution of income
Y = mean income for the whole community

For Ain-Talawi community in Iraq, for example, the calculated Gini coefficient was 0.55, indicating a noticeable degree of income inequality among households in the community. It is worth noting that, due to data limitation; the estimation was based on income level instead of wealth, and thus may not precisely reflect the status of poverty in the community. Income distribution was determined by the distribution of resources and assets among households and the efficiency of using them.

Farmers in this community were classified into three main groups with respect to the type of enterprise. About 26% produced crops only, while 9% raised livestock only. The majority (65%) were of mixed farming enterprises. The third group owned more resources and, thus, more income; it controlled 53% of the total income of the community. Thirty three per cent of the total household income of Ain-Talawi community farmers was from crop production. Livestock producers earned only 15% of the total income of the community (Mashreq/Maghreb Project, 1999/2000 Annual Report).

Guidelines for Adoption and Impact Studies

Adoption studies

Adoption studies are very important for the following reasons:

- Better understanding of farming systems and farming communities
- Identification of constraints (technical, socio-economic, policy) that hinder wide adoption of introduced technologies and working on their solutions
- Improvement of technology adoption and diffusion
- Provision of information for impact studies

There are four basic requirements for a successful adoption of any technology.

1. The technology should be developed and evaluated in the target community.
2. The capital costs should be affordable, and more of the materials inputs should be sourced locally to ensure sustainable adoption.
3. The production methods employed should be relatively simple.

Sampling approach for adoption studies

Data used for adoption studies are generally collected from cross-sectional sample of farmers within the target community. Simple or stratified random sampling should be used for selection of farmers, depending on the technology under investigation. Regardless of the sampling approach used, cross-sectional data from three groups of farmers are recommended for solid adoption studies.

1. *Participants in demonstrations*. This group includes farmers who host demonstrations of the technology under consideration. Many examples can be cited from the experience of the M&M project, which included farmers who hosted the demonstrations of improved barley varieties, barley/vetch rotations, and feed blocks utilization.

2. *Neighbors and/or participants in field days.* This includes farmers and sheep owners who attend field days on the technology under consideration.
3. *Non-participants (reference farmers).* These are farmers who do not host any technology demonstration or attend any field day. They serve as the control group that provide background information concerning farmers' knowledge and perceptions about the technologies.

Criteria for grouping selected farmers
Many criteria can be used to group selected farmers into subgroups in order to study the technology adoption.

1. *Type of participation.* Farmers are grouped into three with respect to their participation in technology evaluation/demonstration. These include participants in demonstrations, field days attendees, and non-participant farmers. Empirical analyses shows that higher adoption rates are associated with farmers who host project demonstrations than in the other two groups.
2. *Type of production systems (e.g., intensive, sedentary, transhumant, etc).* This is particularly important in studying the adoption of livestock technologies, as it is highly likely that adoption rates vary with different production systems. For example, urea-treated straw and sponges are more likely to be adopted faster by sheep owners of intensive and sedentary systems.
3. *Farm/flock size.* Selected farms can be grouped into small, medium and large with respect to farm/flock sizes. Alternatively, grouping can be done according to farm size, such as ≤5ha, 5.1–10ha, 10.1–15ha, and >15ha. Grouping can also be done according to flock size: <50 heads, 50–100 heads, and >100 heads. Previous research has shown that farm/flock size is a key determinant in technology adoption, with higher adoption rates being associated with larger farmers/herders.
4. *Rainfall zone.* Another criterion for grouping sample farms is the rainfall zone. In many countries, rainfed areas are classified into sub-regions based on the annual amount of rainfall. For example, rainfed area in Iraq is subdivided into three rainfall zones, which include low (200–350mm), moderate (350–450mm), and high (>450 mm) rainfall areas. Other countries have similar classification.
5. *Type of enterprise.* Farmers can be grouped based on the type of enterprise — crop producers, livestock producers and mixed (crop and livestock) producers. Farmers of mixed enterprises are more likely to adopt technologies aimed at enhancing crop/livestock integration. For example, crop/livestock producers expected to adopt vetch production.
6. *Land tenure system.* Three land tenure systems are common to all countries in the region. These are individually owned land, rented land (from the State or a private body), and sharecropping. Previous studies have shown the land tenure system is an important factor in technology dissemination and adoption.

Adoption indicators
Three main indicators of adoption can be used in studying the adoption of any technology. These are:

1. *Adoption rate.* This indicator represents the percentage of farmers adopting the technology under consideration. The rate of adoption of a new technology is largely subject to its profitability, the degree of risk associated with it, capital requirements, agricultural policies, and socio-economic characteristics of farmers. Although the adoption rate is an important indicator in measuring technology adoption, especially at the early stage of the project, other indicators are needed at the later stages to better assess the technology uptake.
2. *Degree of adoption.* This is measured using the proportion of land under the new crop cultivar, for example. Similarly, it is measured using the proportion of feed substituted by feed blocks or vetch hay in animal feeding.
3. *Intensity of adoption.* This indicator represents the quantity of modern inputs used, for example, the amount of fertilizers per unit area.

Methodology for adoption studies

The three adoption indicators already discussed can be easily subtracted from the data collected from farm surveys. However, estimating the probability of adoption and analyzing factors affecting the adoption indicators requires advanced modeling. Both probit and logit models are used in applied research on technology adoption. However, the logit model is more common in applications.

A univariate binary model defined as:

$$P(Yi=1) = F(XiBo) \ , \ i = 1,2,\ldots\ldots, n$$

Where: Yi = sequence of dependent binary random variables taking the values of 1 or 0

Xi = K-vector of known constants

Bo = K-vector of unknown parameters

F = a certain known function

The functional forms of F most frequently used in applications are as follows (Amemiya, 1981):

Linear probability model:

$$F(x) = x$$

Probit model:

$$F(X) = (X) = \int_{-\infty}^{x} \frac{1}{root} 2\pi \exp\left[-(t^{2} T) \right] dt$$

Logit model:

$$F(X) = \Omega (X) = \frac{e^{x}}{1+^{e}\ x}$$

The linear probability model has a defect, because F is not a proper distribution function, as it is not constrained to lie between 0 and 1. However, the probit model, like many other models using the normal distribution, may be justified by appealing to a central limit theorem. A major justification for the logit model is that the logistic distribution function is similar to a normal distribution function but has a much simpler form. With regard to probit and logit models, Amemiya (1981) concludes, “Because of the close similarity of the two distributions, it is difficult to distinguish between them statistically unless one has an extremely large number of observations.” The choice between them is largely one of convenience and program availability (Perry et al, 1986).

Both probit and logit models have been used in applied research on technology adoption. The logit model is, however, more common (Kebede et al, 1990; Bagi, 1983; Jarvis, 1981; Sarap and Vashist, 1994). In a study conducted in Iraq on the adoption of barley production technology, both probit and logit models were used to assess the first two objectives, adoption rate and degree of adoption, where the probability of adoption depends on the characteristics of the farmers (Shideed, 1995). If the coefficient of a particular variable is positive, it means that higher values of that variable result in a higher probability of adoption, while a lower value implies a lower probability of adoption (Sarap and Vashist, 1994).

Logistic regression is a popular statistical technique in which the probability of a dichotomous outcome (such as adoption or non-adoption) is related to a set of explanatory variables that are hypothesized to influence the outcome. The logistic regression model characterizing technology adoption by the sample households is as follows:

$$\ln [P_i/(1-P_i)] = B_0 + B_1 X1_i + B_2 X_{2i} + \ldots + B_k X_{ki}$$

Where:

Subscript i = the ith observation in the sample

P = the probability of the outcome

B_0 = the intercept terms

B_1, B_2, …, Bk = the coefficients associated with each explanatory variable X_1, X_2,…, X_k

Please note that the estimated coefficients do not directly indicate the effect of change in the corresponding explanatory variables on the probability (P) of the outcome occurring. Rather the coefficients reflect the effect of individual explanatory variables on its log of odds {Ln [P/(1-P]}. The positive coefficient means that the log of odds increases as the corresponding independent variable increases. The coefficients in the logistic regression are estimated using the maximum likelihood estimation method.

For the adoption studies of M&M Project, probit and logit models can be used to analyze the first two indicators, adoption rate and degree of adoption, where the probability of adoption depends on the characteristics of the farmers. If the coefficient of a particular variable is positive, it means that higher values of that variable result in a higher probability of adoption, while a lower value of a particular variable implies a lower probability of adoption.

The third indicator of adoption, intensity of adoption, can be analyzed using the multiple linear regression model. Number and type of variables to be included in the three models of adoption (probit model, logit model, and multiple linear regression model) depend on the technology under consideration and available data. A study conducted in Iraq on the adoption of barley production technology included several explanatory variables, including farm size, weather risk, farming enterprise and profitability (Shideed, 1997). In consistency with previous literature, the farm size is expected to have a positive relationship with the adoption of crop production technologies like improved varieties and fertilizers.

Attitude of farmers to risk is an important factor influencing the adoption of agricultural production technologies. Risk-averse farmers are typically reluctant to invest in innovations with which they have little first-hand experience.

Farming enterprise is another factor that may affect technology adoption. However, the direction of its effect is undetermined. It could be positive or negative depending on the relative contribution of the enterprise to farm income.

Profitability is the most important determinant of the rate of technology adoption and diffusion. Improved crop varieties/hybrids diffuse more rapidly in areas where it is more profitable than areas where it is less so. Previous research has shown that both the rate and limit of diffusion are positively related to changes in technology's profitability.

Kosarek, Garcia and Morris (2000) investigated factors affecting the hybrid maize diffusion rate using data from 18 countries. Their findings validate conventional profitability-based explanations of producer adoption behavior, but they also confirmed the importance of supply-side factors, thereby providing empirical support for the life cycle theory of seed industry development. They concluded that to accelerate the diffusion of hybrid maize, policy makers must ensure an environment in which it is profitable for producers to adopt improved germplasm, as well as for the seed industry to produce and sell high-quality seed.

Policy environment is a key determinant of adoption of new technologies. A previous study revealed that factors commonly purported to be highly correlated with adoption of conservation production systems were not useful for predicting use of conservation production practices (Robinson and Napier, 2002). Research findings suggest that existing conservation programs are no longer useful policy instruments for motivating land owner-operators to adopt and use production systems designed to reduce agricultural pollution of waterways.

Sall, Norman and Featherstone (2000) demonstrated that farm and farmers' characteristics, as well as farmers' perceptions of technology-specific characteristics significantly influence adoption decisions relating to improved rice varieties. The results of tobit regression analysis including variables representing both farmers' perceptions as well as farm and farmer characteristics were found to be important in determining the decision to adopt and the intensity of adoption of improved rice varieties.

Impact assessment

Investments in agricultural research by the Mashreq/Maghreb Project was intended to generate or increase the stream of benefits from agriculture at the farm, community, and national levels through change in technology adoption, institutional and human capacity building, and policy change. Although more emphasis in previous research was given to measuring the economic impact of the project, institutional impact is equally important. Economic indicators such as income level and its distribution are widely used to evaluate the economic impact of research projects. However, social indicators, such as poverty, must be considered especially in assessing community level impact.

There are a number of issues facing impact assessment of the M&M Project. These include measurements of the technological changes and their benefits, time dimension of the changes and benefits, attribution of the changes to the M&M Project from all other changes that are taking place, and equity and sustainability. More important are the identification of performance indicators and the selection of methodology.

The difference in products of various research programs means that different methods are required to evaluate the impacts of each kind of research. Methods for evaluating the impact of crop breeding research are well established. However, no consensus exists on how to measure the impacts of other research programs.

The process of monitoring the collection of baseline information should be linked to impact analysis. While monitoring is a continuous process throughout the project life, impact analysis is done at some stages of the project. Methodology for analyzing the impact of resource-based and farming system research is not readily available, whereas that for commodity-based, especially crop breeding, is available. However, the project has good experience from the first phase and we can capitalize on it.

Unit of analysis

Although the local unit of analysis is the community, five levels can be considered, depending on data availability. These are farm level, community level, regional level (within the same country), national/market level, and regional level (across countries) impact.

Type of analysis

Impact analysis can be classified into *ex-post* and *ex-ante*, based on the type. *Ex-post* analysis measures the observed impact of a technology based on actual adoption rate and actual yield gain, or cost reduction. *Ex-ante* analysis measures the potential impact of a technology based on expected adoption rate and potential yield gain, or cost reduction. *Ex-ante* analysis requires a few years of price and quantity data (perhaps the most recent three to four years) for a benchmark. On the other hand, *ex-post* analysis typically requires detailed annual data on prices and quantities for a single commodity aggregate of interest for all past years for which benefits are to be assessed.

A general problem of *ex-post* analysis is that of inferring a stream of without-research prices and quantities using time-denominated data with research data that vary partly as a result of variables not included in the model (e.g., weather, policy changes). This is in contrast to *ex-ante* analysis where, by assumption, other things are held equal or are explicitly modeled. Problems of double counting or inappropriate attribution can arise when studies apply a measure of research- or technology-induced supply shift to actual past quantities and prices. One safe way is to conduct an *ex-post* analysis in the same manner as an *ex-ante* analysis by projecting the entire series from a benchmark, in which case the same information is required for benchmarking (Alston, Norton and Pardey, 1995).

Process of implementing impact analysis
Impact assessment involves several interrelated steps. These are:

- *Developing "critical success factors" or "performance indicators."* Two kinds of indicators need to be carefully identified: activity-based indicators and institutional-based indicators. Participants in the regional workshop held in Iraq on 18–21 March 2001 developed the activity-based indicators.
- *Collection of baseline information.* Rapid rural appraisal, formal surveys, and national statistical data are the main sources of baseline information. Annual reports of the M&M project also contain detailed and important data based on on-farm technology evaluation that can be used for baseline information. Previous studies on adoption, monitoring and evaluation, and impact assessment conducted by national programs or other research projects are very useful to complete the set of baseline information.
- *Measuring adoption indicators.* Adoption rate, degree of adoption and intensity of adoption should be calculated to implement impact assessment. That is particularly important for market-level impact using the economic surplus approach.
- *Collection of related data.* In addition to baseline information and adoption rates, there is a need for more data to complete data requirements for impact assessment, especially for market-level impact. For accurate impact assessment, information on yield gain, quantities produced and consumed, price received and paid, price elasticities of supply and demand, planted area, trade and pricing policies is needed for a crop production technology. An *ex-post* analysis typically requires detailed data on prices and quantities for a single commodity aggregate of interest on an annual basis for all past years for which benefits are to be assessed. For tradable goods, it may be appropriate to use the border price (either CIF or FOB) depending on whether the good is importable or exportable. It is necessary to determine whether domestic prices are free market prices or the result of a tax or subsidy policy and to measure the extent of any price intervention. Typically, an impact analysis will be undertaken with all monetary variables expressed in real terms. This can be done by deflating nominal prices by an appropriate index.
- *Measuring the supply shift.* The wide adoption of a technology or research output results in an upward shift in the commodity supply curve. The size of the research- or technology-induced supply shift is a crucial determinant of the total benefits from research/technology. The accuracy of the estimates of the supply shift and its path over time will determine the accuracy and validity of the estimates of research/technology benefits. At the individual farm level, a technology-induced supply shift can be divided into two components: one component arising from changes in productivity that would occur if input use were held constant at the optimum level that applied before the technological change, and the other component associated with changes in the input mix to

optimize input combinations under the new technology.

- *Selection of appropriate approach.* Several approaches are readily available for impact analysis, depending on the unit and type of analysis. The most widely used procedures are budgeting (enterprise or partial), linear programming, structural econometric models, and economic surplus approach. There is no universally best method for impact assessment. Data availability, the economic environment, and the type of results required will jointly determine the most appropriate approach. The following section presents these approaches, supported by some case studies whenever they are available.

Measuring farm level impact

Three methods are commonly used for assessing the economic impacts at the farm level of a technology. The first method is to calculate the relative cost and revenue differences between the proposed technology and the existing production systems within a set of gross margin budgets (e.g., Jolly and Gadbois, 1996; Shideed, 1996). The results from this simple budgeting process can then be used to calculate marginal rates of returns for each technology option. However, there are two frequently cited problems with simple budgeting (Nagy and Sanders, 1990). These are price variations over time and within the production season and cost of non-tradable inputs such as land and family labor. Output prices can vary substantially within a year and between years in regions with substantial climatic fluctuations and limited public policy role in price stabilization. Moreover, input costs depend on government subsidies and the availability of an input, such as fertilizer, at the right place and the right time. Questions about the appropriate prices and costs to be utilized in the budgeting analysis are valid concerns that need to be dealt with in the economic assessment of a new technology. Sensitivity analysis, which varies the prices and costs over the relevant range, can be utilized to respond to this problem.

In spite of the problems of price variation and the cost of non-tradable inputs, profitability comparisons from simple budgets with sensitivity and risk analysis give substantially more information than physical (yield) or technical comparisons alone (Nagy and Sanders, 1990).

Calculating changes in gross margin

The annual total value of an improved technology is:

$$QR_{it} = A_t \, \Delta\pi_{it} \, (K_{it} - K'_{it})$$

Where $\Delta\pi_{it}$ = change in profit per unit area

QR_{it} = Total gross margin generated by innovation i in year t

A_t = Total harvested area in year t.

$(K_{it} - K'_{it})$ = Difference between the percentage adoption of the innovation in year t with M&M project (K_{it}) and the percentage adoption that would have occurred without the M&M Project (K'_{it})

Measuring gross margin

There are two options for calculating the per hectare impact of a given innovation on economic surplus.

1. *Partial budgeting:* A non-statistical method for comparing the costs and benefits of a particular technology. It uses information from farmer-managed trials.
2. *Yield production function:* This approach relates per unit area yield to a set of explanatory variables, such as levels of input use, type of technology and environmental factors. A production function can be specified in its general form as:

$$Y_K = f(X_K, Z_K, I_K, B) + E_K$$

Where:

Y_K = per hectare output of producer k
X_K = vector of variable input levels
Z_K = vector of environmental factors
I_K = vector of improved technologies or management practices
B = vector of coefficient to be estimated
E_K = random error term

$\Delta\pi_i$ = (dY_K/dI_K) P is the impact of the adoption of innovation I on profit, at output price p and holding all other inputs unchanged

The production function approach has several advantages. These include:

- Regression model is capable of statistically isolating the individual effects of production factors.
- Interactions among technologies and inputs can be tested statistically.
- The data used to estimate the production function are taken from farmers themselves, rather than from controlled experiments.

However, the production function has some disadvantages, in that it is more time-consuming to implement than partial budgeting. Furthermore, it requires a large amount of data. Therefore, choice of technique is based on the nature of data available.

The second method is to build a set of representative farm linear programming (LP) models that incorporate the output from the gross margin analyses, but in addition consider the overhead and other costs associated with the adoption of new technology (Griffith et al, 1995). The LP method has the advantage of overcoming the problem of pricing of non-tradable inputs associated with the budgeting analysis. Mathematical programming models can be used, taking into account the implicit values (shadow prices) of the inputs to farmers in the production process. These values indicate how much farmers would be willing to pay for another unit of the input. In contrast, budgeting analysis generally makes arbitrary assumptions about the labor and land markets (Nagy and Sanders, 1990). To sum, gross margin (budgeting) models estimate within-enterprise resource adjustment and LP models are used to estimate between-enterprise resource adjustments.

The third method is multiple regression analysis of farm production data using information obtained from technology adoption surveys (e.g., Macmillan, et al, 1995; Shideed and Ismael, 1996; Sidhu and Baanate, 1981; and Wagle, 1994). Cobb-Douglas and translog production functions are commonly cited forms in the literature (Lyn, et al, 1984). Translog profit function can also be applied to farm level data (Sidhu and Baanante, 1981). Application of the translog profit function to farm level data allows a more disaggregated analysis of the farm production structure than the Cobb-Douglas function. According to Sidhu and Baanante (1981), the flexibility afforded by translog function permits measurements of the different impacts that exogenous variables have within and across input demands and output supply functions.

Logistic regression model can also be used to analyze the impact of a technology. The effects of animal traction, for example, a logistic regression model was used to analyze food self-sufficiency (Jolly and Gadbois, 1996).

Measuring market-level impacts

In the simple case of aggregate impacts and no price effects, the gross annual research benefits (GARB) can be used without regard to research- or technology-induced changes in prices and quantities, and, therefore, without requiring any information on elasticities and market shares. As it is clear, this approach does not require information on price elasticities of demand or supply (assumed zero or infinite) or market share. In addition, it assumes that technological spillovers are absent. Consequently, this approach is unable to deal with the distribution of benefits. It may also result in significant measurement errors. Incorporation of price effects and dis-aggregation of benefits requires alternative methods.

The widely used method in estimating the *ex-ante* market impacts of a production technology is to calculate the economic surplus changes and distributions from the technology adoption. Economic surplus comprises both consumer's and producer's surpluses. The consumer surplus is the difference between the benefits derived from consuming a product and the costs of obtaining it, whereas the producer surplus is the difference between the returns from selling the product and the costs of producing it.

There are two methods for calculating the economic surplus (Grifith et al, 1995). The first method is based on the assumption that technology adoption leads to an outward shift in the product's supply curve. The effect of this shift in the supply curve on producer and consumer surplus can be evaluated using standard formulae. Certain assumptions are required about the slopes of the supply and demand curves, the nature of the supply shift, and the relationship between producer and consumer prices. In addition, some base or initial equilibrium set of prices and quantities are used for making these calculations. The major limitation of this method is that the model is static.

The second method is to simulate the impacts of the new technology on the relevant market variables using a structural econometric model. In simulating these impacts, the values of the market variables or parameters are altered experimentally, the model resolved, and the results compared with the base model solution.

Any changes in prices and quantities assumed to be attributable to the imposed changes resulting from technology adoption can be translated into measures of economic surplus change, which are allocated to producers and consumers according to the supply and demand elasticities. Although the first approach is easier to implement, the second method is more reliable. In addition, a major advantage of the econometric simulation is that the dynamic responses to technology adoption can be traced over time, as the model is solved period-by-period (Griffith et al, 1995). Both the econometric and economic surplus models are used to establish the market level impacts of the technology.

It is commonly accepted that the changes in social surplus (change in total economic surplus) due to a research-induced supply shift – and therefore the returns to research – are robust to different specifications of supply and demand elasticities. Returns to research are thought to be robust under alternative supply elasticity assumptions. Oehmke and Crawford (2002) show conceptually and numerically how advances in approximating social benefits make returns to research sensitive to the supply elasticity.

Regardless of the method chosen to calculate the research/technology benefits, capital budgeting can be used to calculate some criteria to measure the technology impact. One such criterion is the net present value (NPV), which can be calculated using the following formula:

$$NPV = \Sigma(B_t - C_t)/(1 + r)^t$$

Where, r = discount rate
Bt = calculated annual benefits (e.g., total economic surplus)
Ct = annual cost

Bt and Ct are in current real values. Thus, use a real discount rate for discounting benefits and costs streams.

Another criterion in capital budgeting is the benefit-cost (B/C) ratio, calculated as the ratio of present value of gross research benefits to present value of research costs.

Internal rate of return (IRR) is commonly used to measure research efficiency and profitability. It is computed as the discount rate that would result in a value of zero for the net present value. This is expressed mathematically by the following formula:

$$0 = \Sigma (B_t - C_t)/ (1 + IRR)^t$$

Impact of improved cultivars on input demand and productivity

New crop varieties, like any other new technology, may change the optimal levels of inputs used. The profitability of adopting new varieties will depend on how demands for inputs are changed and how large the productivity improvement is. Thus, an understanding of the effect of new varieties on input demand and productivity is crucial for better understanding of potential diffusion of the technology among farmers.

Impact on input demand

Various modeling approaches are used to analyze the influence of improved crop cultivars on the demand for an input. Such impact on the demand for fertilizers, for instance, can be analyzed using partial adjustment models. A theoretical model may take the following form (Wagle, 1994):

$$\text{Lin } Y_t = B_0 + B_1 \text{ Lin } H_t + B_2 \text{ Lin } T_t + B_3 \text{ Lin Pratio} + B_4 \text{ Lin } R_t + B_5 \text{ Lin } Y_t\text{-}1 + U_t$$

Where: Y = amount of fertilizers
H = percentage of irrigated area to total planted area
T = technology variable measured by percentage of the area under improved cultivars to total planted area of the crop
Pratio = price ratio of fertilizer price (or its index) to product price (or its index)
R = index of rainfall (percentage of actual rainfall to normal rainfall); normal = 100

Although the above model is designed to estimate the aggregate impact of the improved-cultivar-technology on the demand for fertilizers using time-series data, it is also applicable for a farm level analysis using cross-sectional data or pooled time series and cross-sectional data. In any case the estimated short- and long-term elasticities will provide indicators to the sensitivity of the demand for fertilizers to the improved cultivars and price changes.

Other empirical estimations of the effects of modern varieties on input demands are based on duality theory (e.g., Lin, 1994 and Sidhu and Baanante, 1981). A model of input demand, based on the assumption of cost minimization, can be derived as follows (Lin, 1994):

We minimize costs on a unit of cultivated area:

$$P'x = C(p,q^*,e)$$

Where: P = vector of input price
x = vector of variable inputs
q^* = expected output level of improved and conventional cultivars
e = vector of household endowments and characteristics and the physical environment in which the farm is located.

The expected output level is related to variable inputs x, the technology d (e.g., improved and conventional barley cultivars), and the household endowments and characteristics:

$$q^* = f(x/d,e)$$

Using Shephard's Lemma on cost function, we get:

$$X_i = \partial\, c(p,q,e)/\partial p_i \qquad \text{for all } i$$

and the explicit demand function in a reduced form for a variable input is:

$$Xi = gi\ (p, d, e)$$

if $\partial xi/\partial pj>0$ (for $i \neq j$), then xi and xj are gross substitutes, whereas $\partial xi/\partial pj<0$ implies that the two inputs are gross complements.

The derived demand function can be estimated using cross-sectional farm level data and appropriate estimation method (e.g., OLS).

A restricted profit function can be also used to estimate jointly the profit and input demand functions from farm level cross-sectional data based on duality theory (Sidhu and Baanante, 1979).

Impact on productivity

Although the effect on demand for inputs is an important property of a new technology, farmers will not accept the technology if it does not raise productivity. For example, on-farm trials and demonstrations have shown that average yields of improved barley cultivars are higher than those of conventional varieties. However, because more chemical fertilizers are used in the production of improved variety, it is difficult to decide whether the yield advantage of improved cultivar simply reflects the impact of differences in the level of fertilizer applications or the technical properties of the improved cultivar. An appropriate technique for assessing the impact of improved cultivars on productivity is the regression analysis. Cobb-Douglas production function is a frequently used formulation for estimating the productivity impact of a new technology. The impact of a new technology on the total factor productivity can be estimated by adding a dummy variable to the function (Lin, 1994).

The empirical production function may take the following form:

$$Lin\ Q = B_0 + \Sigma B_i Lin X_i + \Sigma B_j D_j + \Sigma B_k H_k + V$$

Where: Q = output measured in appropriate units
X_i = variable inputs (planted area, labor, fertilizers, machinery)
Dj = dummy variables for technology, rainfall zones, and farm size
H_k = socioeconomic characteristics of farmers (education, age, etc)
V = error term

Again, farm level cross-sectional data obtained from technology adoption surveys can be used to estimate productivity impacts of improved crop cultivars.

Returns to research and extension

Agricultural research and extension (R&E) has been regarded as a major source of technological change and, thus, productivity improvements. A change in R&E investment would be expected to produce quality changes in inputs and, hence, affect the productivity of inputs, which in turn would affect input-output relationships.

While several approaches have been developed to evaluate these impacts, the production function approach (mainly Cobb-Douglas and translog formulations) is the most widely used in previous literature (e.g., Lyu et al, 1984). With this approach, the R&E variables are inserted directly into the production function in order to measure the impacts of R&E on output. A major advantage of the approach is that it provides estimates of the marginal products of research and extension, as well as of other variables affecting input productivity.

Limited-dependent variable regressions were also used to analyze the impact of training and visit extension system in the irrigated Punjab of Pakistan (Hussain et al, 1994). It was concluded that training and visit program has increased the quality as well as quantity of extension contact, and this in turn has increased farmers' knowledge and adoption of technology.

Multiple regression and least significant difference analysis of farm production data combined to estimate economic returns to research and extension activities (Macmillan et al, 1995). The emphasis is on expected returns at the individual farm level, which differ from the focus on aggregate returns to past research and extension expenditure. The multiple regression analysis of farm data provides baseline information on current management practices and household production. The least significant difference analysis of yields in on-farm trials is usually performed to determine the maximum yield potential of improved varieties and agronomic practices introduced by the project.

In the multiple regression analysis, crop output per household per year (TOTPROD) can be summarized in a production function form as:

TOTPROD = f (variety, agronomic practices, economies of size, capital, labour, environment)

Total production per household is used as the appropriate dependent variable instead of yield per hectare, because food security is the most important household objective. Household size is used as a proxy for labor use, whereas economies of size is measured by the crop acreage squared.

The next step is to estimate the benefits from research. Different techniques are used to estimate benefits from the adoption of improved farm technologies. A commonly used method is the producer-consumer surplus model. This method requires assumptions about the nature of shifts in the output supply curve and reliable price elasticities of demand and supply curves, which may not be available.

Another approach for estimating benefits from research is the cost-benefit analysis. Under this method, the present value of expected future benefits of production changes can be compared with the present value of the costs of research and extension activities. A stream of net returns to research and extension and costs of a crop research can be estimated for appropriate period. The data required include price of the crop, yield gains, costs of production, and diffusion rate of improved varieties and their expected economic life. The model for estimating economic benefits is (Aw-Hassan et al, 1995):

$$B_t = P_t.Q_t.g_t - C_t$$

Where $g_t = (1 - Y_1/Y_m)A_{tm}$

B_t = undiscounted benefits from research and extension in year t
P_t and Q_t = price and quantity of the crop in year t
g_t = annual growth in crop production estimated by multiplying the per centage yield gain by the proportion of area cultivated to the modern variety in year t (A_{tm}), Y_m and Y_1 = average yields of the modern and traditional varieties, respectively
C_t = increase in cost of production due to the use of modern varieties and agronomic practices

The technological change, measured as yield gains, is estimated from the results of on-farm research trials. Alternatively, the regression coefficients for total household production estimated from the farm survey data can be used to measure the additional production per household as a result of adopting modern varieties. The benefit-cost (B/C) can be estimated as follows:

$$B/C = \Sigma_t [B_t/(1+r)^t]/\Sigma_t[C_t/(1+r)^t]$$

Where r is a discount rate. The internal rate of return (IRR) is calculated as the discount rate, which makes B-C =0.

Benefit-cost analysis can be extended to account for production variability by introducing probability distributions for benefits and costs to account for droughts and other environmental conditions.

Technology impact and risk considerations

Production risk, such as the inter- and intra-year variability of rainfall, can affect the profitability and, hence, the acceptance of a technology by farmers. Empirical analysis of production risk is often difficult because of data, information and methodological deficiencies. A crude but simple method is to determine the percentage of farmers in the farmer-managed trials who would have lost cash from using the technology (Nagy and Sanders, 1990).

Index of variation ([Standard Deviation/Mean] × 100) is another risk analysis method that can be calculated from the on-farm trials. The index of variation can be used to rank the treatments with respect to their yield-risk effects.

Market forces represent another major source of risk. Sensitivity analysis, which varies the prices and costs over the relevant range, can be utilized to respond to this problem. Some innovations may be sensitive to small changes in prices or costs, which may alter their relative profitability ranking. This justifies the need for risk analysis in relation to the transformation of agricultural technology. Farmers' perceptions of the level of risk comprised a major factor in the success or failure of technology transfer.

Decision-making under uncertainty

It is assumed that the objective of the rational producer is to maximize utility derived from present and future consumption. The conventional method of empirical analysis in an expected utility framework is to consider the trade-off between expected value and variance of income (net return), commonly identified as E-V analysis. E-V analysis has been extensively used by agricultural economists for various applications (e.g., Collender, 1989; Kaiser and Boehlje, 1995; and Musser, Tew and Epperson, 1981). E-V analysis is convenient to compute but has some serious limitations. It requires that either the decision-maker has a quadratic utility function or that net return is normally distributed. Both assumptions seem to lack support from a practical viewpoint for use in on-farm decision-making.

Another widely used approach regarding decision-making under uncertainty is the mean absolute deviation (MOTAD) analysis. MOTAD has an advantage of E-V analysis in that it uses a linear programming algorithm in deriving efficient farm plans, thus simplifying computations. However, the MOTAD model provides an estimator of variance that is less efficient than that of E-V, and, in general, the results cannot be expected to be as reliable (Hazell, 1971).

To avoid these difficulties, the stochastic dominance (SD) technique has been largely used, especially for analysis involving discrete alternatives (e.g., Kramer and Pope, 1981; King and Robinson, 1981; Mazid and Bailey, 1992; and Shideed and Adary, 1994). Stochastic dominance is an alternative technique in an expected utility framework that does not require the restrictive assumptions of E-V analysis. However, given a single-valued utility function with net returns as the only argument, assumptions about preferences of the producers are needed. As a decision criterion, SD generally states that a risky prospect dominates another stochastically if the consequences of the dominant distribution for all possible values within a specified range are preferred for at least one value (Anderson, Dillon and Hardaker, 1977).

There are certain degrees of stochastic dominance, depending on the assumptions regarding a decision-maker's behavior. The first degree stochastic dominance (FSD) is based on the assumption that the decision-maker prefers more net returns to less. This implies a positive first derivative for the decision-maker's utility function with respect to net returns. Use of the FSD is very limited because only a few alternative actions would be eliminated by the FSD ordering rule.

The second degree stochastic dominance (SSD) approach is based on the behavioral assumption that the decision-maker has an increasing utility function of net returns as well as risk averse. For SSD, it is necessary for the second derivative of the utility function to be negative.

Third degree stochastic dominance (TSD) refines the efficiency set identified by SSD by imposing a third restriction on the utility function in that its third derivative should be positive. TSD is not commonly used because of the lack of an empirical and theoretical justification for its assumption on the shape of the utility function and in many cases the SSD efficient set was not reduced with TSD.

Empirical example

To illustrate the practical application of the material presented in this section, consider the information presented in Table 1.1. These data were calculated from studies on farmers' fields in rainfed areas of limited rainfall in Iraq. The objective was to compare fertilized and unfertilized treatments of two barley varieties, 'Jazera-1' and a local (black) variety, under two technological packages: full package and farmer package. As a result, a total of five alternatives were obtained under each technological package (Shideed and Adary, 1994). These were jazera variety with and without fertilizer (JF+ and JF-), local variety with and without fertilizer (LF+ and Lf-) and conventional farming (conv.). The information in Table 1.1 shows that fertilized treatment of 'Jazera-1' offers higher net returns on the average than other alternatives for both technological packages. However, as the standard deviations indicate, the net returns from this alternative are subject to a greater degree of location-to-location variability. Other alternatives also have lower standard deviations but lower net returns. Thus, the data verifies that there is a risk-return trade-off. There are several decision rules to follow when choosing among these alternatives based on expected return and risk. It may be desirable to select the alternative that offers the least risk per dollar of net return. This measure is given by the coefficient of variation. Accordingly, fertilized treatment of both varieties offered less risk per dollar of expected return under the full package and would be preferred. Unfertilized treatment of the local variety provided less risk per dollar of net return under the farmer package.

Table 1.1 **Mean, standard deviation and coefficient of variation for net returns of barley under different varieties and alternative practices**

Variety/ Fertilizer	Full package			Farmer package		
	Mean (ID/H)	SD (ID/H)	CV (ID/H)	Mean (ID/H)	SD	CV
JF+	2724.9	1079.4	0.396	2673.1	1222.7	0.457
JF-	1606.9	707.6	0.440	1398.4	653.2	0.467
LF+	2390.5	870.2	0.364	2148.6	879.1	0.409
LF-	1451.7	703.0	0.484	1233.6	466.7	0.378
Conv.	1476.9	687.3	0.465	1008.7	854.6	0.846

JF+ = Jazera variety with fertilizer; JF- = Jazera variety without fertilizer;
LF+ = Local variety with fertilizer; LF- = Local variety without fertilizer
Conv. = Conventional farmer practice; CV= Coefficient of variation
SD = Standard deviation; ID/H= Iraqi Dinar per hectare

Although the coefficient of variation is a useful rule in many situations, it does not account for the risk-return trade-off represented by the decision-maker's risk-return utility function. Given the difficulties in empirical estimation of utility functions, and to avoid the restrictive assumptions of the (E-V) criterion, the first and second degree stochastic dominance criteria were used. The results in Table 1.2 indicate that a risk-averse producer should apply fertilizer to either Jazera or local variety under full package technology. The farmer should use fertilizer with the Jazera variety alone under farmer package technology.

Table 1.2 **Stochastically efficient solution of barley and fertilizer**

Variety/fertilizer		Full package	Farmer package
JF+	SSD	SSD	
JF-	0	0	
LF+	SSD	FSD	
LF-	0	0	
Conv.	0	0	

0 = inefficiency according to first degree stochastic dominance
SSD = efficiency according to second degree stochastic dominance
JF+ = Jazera variety with fertilizer; JF- = Jazera variety without fertilizer
LF+ = Local variety with fertilizer; LF- = Local variety without fertilizer
Conv. = Conventional farmer practice

Empirical Issues in Impact Assessment

There are four major issues confronting the implementation of impact studies. These are:

- Methodological issues concerning the choice of an appropriate method to be used in impact assessment.
- Institutional impact. This is the most important issue, as it is difficult to quantify the institutional impacts. However, documentation of such impacts at various levels is very important.
- National capacity. A necessary condition for successfully implementing impact studies is to have a qualified national team with needed skills in economic training.
- Technology uptake/dissemination/testing. It is crucial for a technology to be tested on farmer's fields/flocks before it can be widely accepted and disseminated among farmers. Adoption rate is a major component in an impact study.

Community Level Impact

Although it is easier to conduct farm level impact for an individual commodity/technology, impacts at the national and community levels require further attention. To conduct impact assessment at the community level, calculate benefits and costs as well as related internal rates of return (IRR) for each technology/management practice and for a group of technologies (e.g., livestock technologies and crop technologies). Then, combine the analysis for all crop and livestock technologies to evaluate the impact of the M&M project at the community level. Calculation of IRR for livestock and crop technologies will provide information on the efficiency/profitability of research investments in livestock or crop technologies (i.e., the higher the IRR, the more profitable the investment). The difference in technology performance (e.g., yield gain of an improved variety) in each community will result in varying IRR's and, thus, variant research efficiency by community.

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2

Regional Synthesis of Adoption and Economic Impact of Improved Technologies in Mashreq and Maghreb Countries

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Based on the stage of technology development (testing, demonstration and dissemination) and availability of data, the technologies of improved barley varieties, feed blocks, introduction of vetch (*bekia*) into barley rotation, cactus, *Atriplex* plantation, and early weaning were subjected to in-depth analyses. This chapter summarizes the results of several case studies conducted in Mashreq and Maghreb countries with respect to:

- evaluating the status of technology profile in each country;
- documenting the farm level adoption of introduced technologies by farmers and sheep owners; and
- assessing the impact of improved technologies on crop and livestock productivity, farm income level and distribution, food/feed security, factor demand and risk reduction.

In implementing the adoption and impact studies, several issues were taken into consideration, such as:

- By nature the crop and livestock production systems in the low rainfall areas (the targeted areas of the M&M Project) of WANA region are confronted with high weather variability in terms of rainfall quantity and distribution, and have been subject to severe drought. Therefore, three states of nature, drought seasons, normal seasons and good seasons, were taken into consideration in assessing technology performance and its impact on productivity. After careful study of the historical weather information before and during the project life, we found that the associated probabilities with the three states of nature vary from one country to another. Drought seasons were assigned a probability of 0.3–0.5, normal seasons were assigned a probability of 0.3–0.4, while good seasons were assigned a probability of 0.1–0.3. These probabilities were used together with the corresponding yield levels to calculate a weighted average for the productivity of the technology under study.
- All adoption studies were based on on-farm surveys for representative sample. Adoption indicators were then calculated for the whole sample and for sub-

groups of the sample (type of participation in the M&M activities, farm/flock size, type of land tenure, type of enterprise). We found that farm and flock sizes in Mashreq countries are generally larger than those in Maghreb countries. Therefore, the distinction in Table 2.1 was made in the sizes of small, medium and large farms/flocks in the two sub-regions.

Table 2.1 **Farm and flock sizes in Mashreq and Maghreb countries**

Farm/flock size	Mashreq countries	Maghreb countries
Farm size (hectare)		
Small	< 10	< 10
Medium	10.1-50	10.1-20
Large	> 50	> 20
Flock size (head)		
Small	< 50	< 10
Medium	51-250	10.1-30
Large	> 250	> 30

- Countries were at different stages of technology development. Some technologies such as improved barley varieties were at the dissemination stage in all countries. Other technologies such as feed blocks were at the dissemination and commercialization stage in Iraq, Jordan and Tunisia, and at demonstration stage in Morocco and Algeria. Similarly, cactus was at the dissemination stage in Tunisia and Algeria and at demonstration stage in Jordan. This difference in the profile of technology development among the eight countries required both *ex-post* and *ex-ante* types of impact assessment. Table 2.2 summarizes the status of technology development in Mashreq and Maghreb countries.

Table 2.2 **Stage of technology development**

Technology	Algeria	Iraq	Jordan	Lebanon	Libya	Morocco	Syria	Tunisia
Cactus	A	T	D	-	A	D	T	A
Rams	D	A	-	A	D	-	A	A
Barley varieties	A	A	A	A	A	A	A	A
Vetch	-	A	A	D	-	-	A	A
F. Blocks	D	A	A	D	D	A	T	A
Shrubs: *Atriplex*	-	D	-	-	-	D	-	-
Alley cropping	-	D	-	-	-	D	-	-
Early weaning	-	-	A	-	-	-	A	-

T = testing stage; D = demonstration stage; A = adoption/dissemination stage

- = technology was not introduced in the corresponding country

- There was difficulty in pricing forage legumes for impact assessment, as the market for such crops has not developed yet, especially in Mashreq countries.

Therefore, two approaches were used in evaluating the economic benefits of the forage legumes. The first one was based on the opportunity cost concept by pricing the forage crop at the price level of the alternative crop, which is barley. The second approach was based on additional return obtained from sheep as a result of the increase in body weight gain and milk production due to the use of forage crop in sheep feeding.

- Some of the developed technologies for low rainfall areas, such as cactus and shrub plantation, are location specific. Therefore, such technologies are not expected to have a wide market level impact. Accordingly, farm level impact is more relevant in this case.
- Two types of impact studies (*ex-post* and *ex-ante*) were implemented using econometric, budgeting and economic surplus models. The next step involves the identification of performance indicators and relevant methodologies for impact assessment. The selected case studies were implemented to assess technology impact on farm income and its distribution, household food/feed security and productivity. Benefits and costs associated with each technology were carefully assessed to calculate the internal rate of return (IRR) and benefit-cost ratio. Risks faced by farmers under rainfed conditions were taken into consideration in assessing the performance of the technology.
- Cactus adoption and impact were studied in Algeria and Tunisia. Improved barley varieties were assessed in Iraq, Jordan, Lebanon, Libya, Morocco and Syria. Improved rams were studied in Algeria and Tunisia. Vetch was analyzed in Iraq, Jordan and Tunisia. Adoption and impact of feed blocks was assessed in Iraq, Jordan, and Tunisia. Shrub and alley cropping plantation was assessed in Morocco. Early weaning technology was analyzed in Jordan and Syria. A synthesis of the selected case studies is presented in the next sub-section.

Empirical Results of Assessing the Adoption and Economic Impact of Introduced Technologies

Results from the various methodologies used in assessing the adoption and impact for the selected technologies clearly demonstrate the economic feasibility of the introduced technologies.

Adoption and impact of feed blocks technology

The feed block technology is subject to continuous economic evaluation in order to monitor its adoption among sheep owners. For the purposes of this study, information on 81 sheep owners in Iraq was collected, including flock size, amount of feed block bought, and number of times a sheep owner buys the feed blocks during the season. The information revealed that sheep owners of all flock sizes used feed blocks to supplement sheep feeding.

To assess the use of feed blocks on a sustainable basis in Iraq, the frequency of buying feed blocks by sheep owners was recorded. Results show that 53% of sheep owners bought feed blocks only once during the season, while 31% bought feed blocks twice. More interesting is that some 16% of the sheep owners bought feed blocks 3–7 times in one season, implying that those farmers depended mainly on feed blocks to feed their animals. On average, sheep owners bought feed blocks twice during the 1999/2000 season, implying the use of the technology on a sustainable basis.

Farm survey data of 156 farmers were collected in Jordan to assess the adoption and impact of feed blocks. Results show that adoption rate of the technology was 21%. Benefits of feed block supplementation were tremendous in all countries. Among benefits observed in Jordan are:

- A daily weight gain of 30kg/head/day for sheep fed on feed blocks, which is equivalent to feeding 200gm of barley a day.
- Improved ewe fertility by more than 18% and daily weight gain by 36–52%.
- Improved daily weight gain of lambs by 12–50% over lambs fed only on barley grain.
- Use of feed blocks could replace 20–50% of concentrate feed consumed by animals.

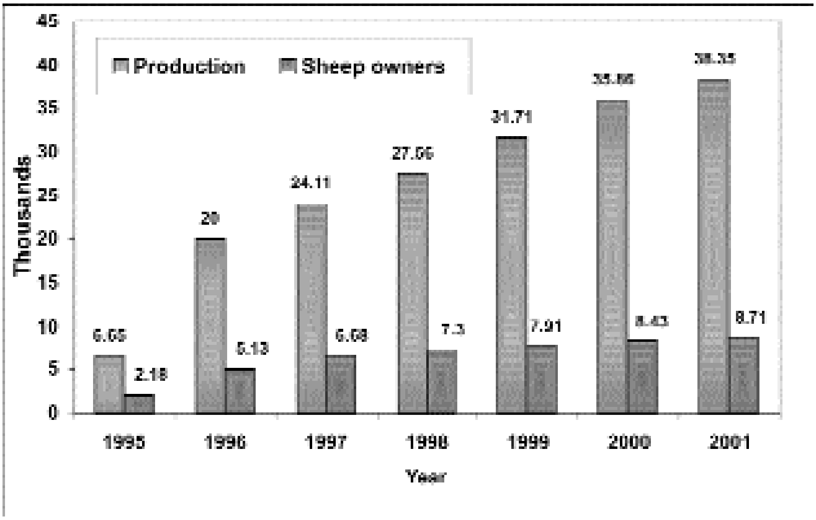
In Morocco, 32% of sheep owners in the targeted community adopted the feed block technology. Likewise, adoption and impact of feed blocks technology was evident in Tunisia. The overall adoption rate among all sheep owners in Zoghmar community was 13%, compared to 54% among farmers participating in the activities on M&M project. This high adoption rate among participating farmers clearly supports the effectiveness of the technology transfer mechanism of the M&M Project. Adoption rate at the national level was 9.4% during 2001/2002 season. The adoption of this technology will help to save about 90 million Tunisian Dinar per year because of substituting high-priced feed.

Previous on-farm demonstrations and on-station trials have shown the importance of feed blocks in improving the efficiency of sheep production. The use of feed blocks resulted in increasing sheep production efficiency by 32% in Iraq as a result of increasing reproductive efficiency and, thus, increasing the number of lambs born. Results show that additional meat production of 4.09kg/ewe/year was attributed to the use of feed blocks. Similarly, additional milk production of 8.28 kg/ewe/year was attributed to feed blocks. This additional meat and milk production requires a total intake of feed blocks of 116kg/ewe/year in addition to the use of conventional feed resources (barley grain, straw and green fodder). To assess the economic feasibility of using feed blocks in sheep feeding, benefit-cost ratio (B/C ratio) and IRR were calculated using the corresponding adoption rates and performance indicators for each country. Based on the analyses the present value of benefits associated with additional meat and milk production can be compared with the present value of the costs of feed blocks used in animal diet. For Iraq, the B/C ratio was 1.56 and the IRR was 67%. These results indicate that high economic returns are associated with the use of feed blocks in sheep feeding. The B/C ratio implies that an additional return of 0.56 Iraqi Dinar is associated with each Dinar invested in feed blocks. Comparing the IRR of 87% with the effective rate of interest of 10% indicates that investments in feed blocks for sheep feeding pay high dividends.

Box 2.1: Diffusion of feed block technology

Multi-nutrient feed blocks are made from locally available agro-industrial by-products and other ingredients. Ingredients vary from country to country, but can include rice bran, sugar beet pulp (after processing for sugar), date pulp, olive cake (the residue from oil processing), residue from the production of tomato paste, by-products from the processing of dairy products, such as the whey of milk, and waste from intensive poultry production units. The ingredients are mixed, baked and pressed in block form using simple equipment. The blocks can also be enriched with vitamins and/or minerals. Diffusion of this technology is progressing very well in most participating countries, especially Iraq where feed blocks have been transferred widely to farmers through private investors. Under the M&M project, the feed block technology was spread to other participating countries, especially Jordan, Morocco, Tunisia and Algeria. An important contribution of the project was to accelerate spillover or the movement of technologies between countries. The M&M project also accelerated the introduction of drought-resistant plants, cactus and *Atriplex,* into Mashreq countries (Iraq, Jordan and Syria).

The development of feed-block technology in Iraq (000 tons)



Feed blocks contributed substantially to feed resources during drought seasons. Some 11.4kg of feed blocks per head was made available during the drought season of 1999/2000, and a maximum of 85kg per head was used by some sheep owners during this season. Considering the drought conditions, when not many alternative feed resources of high nutritive value were available, the feed blocks effectively bridged the feed gap for many sheep owners.

The feed block technology has greatly reduced feeding costs in Tunisia. The technology is being widely used to substitute expensive feed resources such as barley grain and wheat bran, while maintaining the same weights for small ruminants. The estimated IRR of 57% clearly demonstrates the economic feasibility of feed block technology in sheep feeding.

Adoption and economic impact of cactus

The adoption and economic impact of cactus were studied in Algeria and Tunisia. In Algeria, adoption rate in Sidi-Fredj community was 40% and the degree of adoption was 33%. The corresponding internal rate of returns ranged from 71% to 99%, depending on production allocation for fruit and/or feed consumption. It is worth noting that this community is subject to long periods of drought. Indeed, during the last 20 years, 13 seasons witnessed rainfall lower than the average, with nine successive years less than 250mm per year. Therefore, livestock remains the principal source of income for many households in the community, and cactus was the main feed resource available.

The adoption rate of cactus in Zoghmar community of Tunisia was 46%, and it was planted on 50% of marginal land. In this community, cactus helped to reduce fallow land and degraded rangelands by about 50%. Climate variation expressed in terms of drought occurrence was taken into consideration in calculating the IRR of cactus plantation. Average probabilities of 40%, 30%, and 30% were used for average years, drought years and good years respectively. We also assumed that only cactus pads were used for animal feeding. Fruit production was not considered since it is used mainly for domestic consumption or marketing. Another factor

Box 2.2: The diffusion of cactus technology from Maghreb to Mashreq countries

Cactus, which is well adapted to the harsh environments of the dry areas, especially when combined with water harvesting techniques, represents a productive feed option for farmers in the dry areas, and provides means of protecting the natural resource base by controlling soil erosion, particularly on sloping land.

As a result of the Mashreq/Maghreb Project, the experience of the Maghreb countries in cactus production and utilization as a feed was transferred to the Mashreq countries, in addition to Libya in the Maghreb. The exchange of experience, knowledge and expertise achieved within the Mashreq/Maghreb Project had a strong multiplier effect. The benefits of cactus plantation can be summarized as follows:

- Cactus is used as fodder bank for livestock. It can survive harsh conditions of only 150mm of annual average rainfall.
- Cactus pads were commonly chopped in slices and fed to the animals.
- Spineless cactus can also be used to control desertification caused by wind erosion and sand dune movements.
- Use of cactus in animal feeding can substantially reduce water consumption.

included in the calculations was the cost of agricultural authorities working on cactus diffusion, estimated at 10 Tunisian Dinar per person per hectare per year during the first four years of crop establishment. As a result, the IRR for cactus in Tunisia ranged from 73% to 80% when planted in natural rangeland. The upper limit of the estimates accounted for estimates of the performance of the technology with government subsidy, while the lower limit indicates estimate without government subsidy. Similarly, the IRR of cactus in marginal cereal land ranged from 61 to 66%. However, the IRR for cactus plantation in the form of alley cropping with barley in marginal cereal lands ranged from 81% to 89%. The increase in IRR under alley cropping was solely attributed to the barley planted with cactus. A similar conclusion applies to the calculated IRR of cactus in Algeria of 71–99%.

These results clearly demonstrate that cactus is a profitable crop for arid and semi-arid environments. It is profitable because of its various products, low establishment, and maintenance costs. It also allows farmers to crop cereals on marginal lands to control erosion, especially on sloppy lands.

Likewise, the estimated IRR of *Atriplex* plantation with barley (alley cropping) in Morocco was 79%, indicating the efficiency of research investment in this technology, while for barley cropping alone it was 59%. These results support the conclusion that an additional 20% in the efficiency of research investment is usually achieved under alley cropping of *Atriplex* and barley, compared to barley cropping alone.

Adoption and economic impact of improved barley varieties

One hundred and sixty five barley producers were surveyed in Iraq to evaluate the sustainability of adoption of improved barley varieties. Results show that adoption rate of the improved cultivars was 60%, and 54% of barley area was planted with the improved varieties. According to the farmers, the high adoption rate can be attributed to the high grain yield, resistance to lodging and high selling price.

Farm survey data of 156 farmers were collected in Jordan to assess the adoption and impact of improved barley cultivars, feed blocks, bekia and early weaning. Results show that adoption rate of improved barley was 58%, and was planted on 67% of barley area (degree of adoption). The adoption rates of bekia and early weaning were 28.5% and 28.8% respectively. The type of enterprise had an important impact on technology adoption. Mixed (crop and livestock) production systems had the highest adoption rates for all technologies. In addition, land tenure had noticeable impact on the adoption of improved barley varieties and bekia.

Adoption rate of improved barley varieties in Syria was 32%, whereas the degree of adoption was 21.4%, implying that about 21% of barley area was planted with the improved varieties. Participation in project activities had an important impact on the adoption of improved barley varieties. It was noted that farm size had an influence on adoption of a technology. The highest adoption rate was among small farmers, although only 21% of the barley area was allocated for the improved varieties. Both adoption rate and degree of adoption were highest among farmers practicing mixed crop and livestock production. This result has important implications for enhancing crop and livestock integration at the farm level through providing more feed from the adoption of improved barley varieties.

Adoption rate of improved barley varieties in Lebanon was 20% in Arsal community and 11% in Der Al-Ahmar. The corresponding degrees of adoption were 15% and 56% respectively. Farm size had an important impact on technology adoption. The impact of improved barley varieties in Lebanon led to an increase in productivity and a reduction in income inequality. The use of improved varieties will increase total factor productivity by 19% and 23% in Arsal and Der Al-Ahmar communities respectively. The calculated Gini coefficients for local and improved varieties demonstrate an improvement in income distribution as a result of using the improved varieties. The use of improved varieties reduced the Gini coefficient from 0.92 to 0.26 in Arsal community. Likewise, it reduced the Gini coefficient from 0.22 to 0.11 in Der Al- Ahmar community. Thus, improved barley varieties contribute to reductions in income inequalities.

Improved barley varieties were adopted by 17% of farmers in Libya and 46% of sample farmers in Morocco. The corresponding degrees of adoption were 12% in Libya and 40% in Morocco.

Improved barley varieties, in combination with fertilizers, led to 43% increase in barley yield. The net impact of the improved varieties was 19% increase in barley productivity. This means that under the same input levels the improved varieties had a yield advantage of 19% over the local variety.

Box 2.3: Adoption and impact of improved barley varieties

Diffusion of new barley cultivars progressed well in all M&M countries. This process continued with more adaptation investments by national scientists and consequently new cultivars. Farm surveys and impact assessment studies clearly demonstrated the efficiency of research investments in barley production technologies. New barley cultivars increased total factor productivity in targeted zones/communities by as much as 35%, compared to local varieties (see table below). The increase in barley production contributed greatly to household food and feed security. It further supports crop/livestock integration at the farm level.

Adoption of improved barley cultivars and impact on productivity

Country	Adoption rate (%)	Adoption degree (%)*	Impact on productivity (%)
Iraq	60	54	17
Jordan	55	67	25
Lebanon	11–20	15–56	19–23
Libya	17	12	
Morocco	46	40	35 (grain), -12 (straw)
Syria	32	21	20

** Adoption degree is the percentage of land planted with improved varieties.*

In Syria, net impact was 20%, suggesting that planting both improved and local varieties at the same input levels would result in a yield gain of 20% as a result of the biological characteristics of the improved varieties. In addition, the use of improved barley varieties had an impact on the poverty status of barley producers. The calculated Gini coefficient was 0.69 among adopters of the improved variety, compared to 0.82 for non-adopters. Household food security (kg barley grain/household/year) improved by 14% compared to the local varieties.

In Morocco, the improved varieties increased barley grain yield by 35%. However, the straw yield decreased by 12% compared to local varieties. However, this trade-off between grain and straw yield did not affect the economic feasibility of the improved varieties. The improved varieties contributed greatly to feed security, as they increased feed availability by 0.175ton/head annually.

The impact of improved barley varieties on income distribution was neutral. The estimated Gini coefficients were 0.14 for local varieties and 0.13 for improved varieties, implying that improved varieties do not disturb the income distribution of farmers in Morocco.

Adoption and economic impact of early weaning

Sheep owners traditionally leave lambs for prolonged suckling, which may exceed three months. Research shows that the 6-month body weight does not differ significantly for lambs suckling for one, two or three months. A major portion (60%) of milk is produced during the first three months of lambing, hence, if lambs are weaned early, the farmer may increase his net return by selling the milk saved by the weaning technology. Early weaning is performed gradually at three weeks of age by milking ewes once a day. Results of demonstrations in Jordan and Syria showed a considerable increase in milk production. Therefore, early weaning of lambs increased the economic benefits of sheep owners as a result of the extra milk saved; average milk production increased by up to 20kg/ewe in Jordan and 30kg/ewe in Syria without any detrimental effect on lambs feeding on appropriate resources.

Furthermore, with the provision of appropriate feed, like grazing vetch, early weaning improved the daily weight gains of the lambs. Early weaning offers an opportunity for farmers to fatten lambs earlier and deliver them to the peri-urban market-oriented specialized fattening lots that are developing in Syria and Jordan, thereby saving their feed resources. Results of early weaning of lambs in Jordan obtained from a sample of 155 farmers showed a considerable increase in milk production. The early supply of milk as a result of adopting this technology, when the season price is high, also resulted in a substantial increase in farmers' income. In general, early weaning does not affect the total weight gains of lambs. An average of 0.0387 Jordanian dinar was associated with this practice per lamb as additional feed costs, while the additional revenue was 7 Jordanian dinar per lamb. Thus, the additional net revenue to the farmer resulting from early weaning was 6.96 Jordanian dinar per lamb.

Similarly, results of on-farm survey in Syria provided further support to the economic feasibility of early weaning technology.

Adoption and economic impact of improved rams
The traditional extensive production systems of Mashreq and Maghreb are characterized by low livestock fertility, which is attributed to the harsh environment, poor nutrition and low conception rate. Applied research has focused on improving feed sources and supplementation, and improving fertility and reproduction, through the use of improved rams and hormone treatment. In the Mashreq and Maghreb regions, genetic improvement of farmers' flocks is based on identifying rams that have the genetic potential to improve milk production and growth rates of their offspring. Improved rams have been distributed to farmers regularly in all countries, especially Iraq, Syria, Jordan, Algeria, Morocco and Tunisia. The adoption rate of improved rams in Tunisia was 21%. The distributed lambs were used to mate about 18% of sheep population in Zoghmar community. Higher adoption indicators were obtained with large flock sizes. Adopting of this technology led to an increase of 2.2–9.9 Tunisian dinar in the benefits of each lamb produced due to increased body live weight.

In Algeria, about 6% of sheep owners in a targeted community in Algeria adopted the improved rams, and 16% of the sheep population in the community were mated by the improved rams. Results show the major benefits of using improved rams to include:

- Increased rate of prolificacy by up to 118%.
- Increased fertility by 89–94%, compared to that of the farmer practice of 77–83% in an intensive system and 60% in an extensive system on pastures.
- Increased twinning rate from 2.5% to between 25 and 35%.
- Reduced mortality rate from between 18 and 20% to 6% at age 0–3 months.

Adoption and economic impact of forage legumes
A key thrust in improving on-farm feed production was the promotion of rotations that include alternative forage legumes (e.g., species of *Vicia* and *Lathyrus*) in rotation with barley to replace the common practice of fallow.

Introduction of forage legumes into barley rotation in Iraq was subject to comprehensive analysis to determine the efficiency of crop rotation within the framework of risk analysis. Production functions were estimated using pooled cross-sectional data for four locations and time series for the 1991/1992–1997/1998 period. The estimated production functions were used to predict yield levels of barley (grain) and forage legumes (forage) using historical rainfall data for the 1974–1998 period. These predicted yield levels were then used to calculate net returns for the five crop rotations: barley/vicia, barley/medic, barley/vicia-barley mixture, barley/barley and barley/fallow.

Results indicate that the rotations of barley/vicia, barley/mixture and barley/fallow dominated the other alternatives, and thus should be recommended for the LRA in Iraq. It should be noted that barley/fallow rotation was one of the efficient rotations although its net return was not the highest. The main explanation for this is that its coefficient of variation is relatively low. More information on farmers' preferences and objectives is needed for selecting any rotation of the recommended set. For farmers on mixed crop/livestock enterprises, the rotation of barley/vicia and barley/mixture are recommended as they serve the goal of crop/livestock integration better.

In Tunisia, the adoption rate of vetch was 10% among farmers participating in the project activities. The use of vetch resulted in an additional profit of 185 Tunisian dinar compared to fallow. The main constraint to its wide adoption in Tunisia was the limited availability of seeds. This constraint was reduced in Iraq by developing informal seed production by farmers. The adoption rate of vetch technology in Jordan was 29% among farmers of mixed crop and livestock production systems.

3

Adoption and Impact Assessment Studies in Algeria: Cactus Production and Ram Effect

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Current land use patterns in the low rainfall areas of Algeria are unsustainable and are a threat to the future productivity of the resource base. This may in turn undermine any sustainable livelihoods of local communities in these areas. On the other hand, available technologies that could help reverse this situation are not widely disseminated, and whenever they are, are not widely adopted, especially in the marginal farming areas with less than 250mm annual rainfall. However, technology alone is unlikely to solve these problems, and they will worsen with increasing population and income growth if significant policy and institutional arrangements are not incorporated. To adequately address technological, institutional, and policy options in an integrated manner by integrating crop/livestock production systems in the low rainfall areas of Algeria, the Mashreq/Maghreb Project was implemented in two pilot communities, Sidi-Fredj and Mitoussa. Two main technologies, cactus (*Opuntia*) plantation instead of durum wheat, and improved rams, among others, were widely demonstrated and adopted in these two communities. The main purpose of this country report is to document the adoption indicators of the two technologies and assess their economic impacts.

Uses of *Opuntia*

Opuntia is commonly known as "prickly pear" or cactus. It is a species of shrub adapted to the ecological conditions of semi-arid and arid zones. It is used for human consumption as fruit and for animal feed as rackets. As feed, cactus is usually provided as a supplementary diet at a rate of 5kg/head/day despite its low nutritive value (0.72UF/kg).

In 1992, the High Commission for the Development of the Steppe (HCDS) initiated a project to plant *Opuntia* within the government strategic framework to address feed scarcity in the arid areas. An example of such areas is Sidi-Fredj, where water erosion and salinization constitute a serious threat to natural resources (soil and water) and sustainability of production systems.

At the time of this study, the *Opuntia* area was 1280 hectares, planted by 235 farmers. The average area cropped to *Opuntia* by farmers was 3–5 hectares each, out of an average farm size of 12.5–23 hectares.

Comparison between Production Costs and Returns of *Opuntia* and Cereal Systems

Table 3.1 presents the costs and benefits of replacing the cereal system (durum wheat) with *Opuntia*. The partial budgeting of the new system depicts increased cost (C+) and reduced profit (P-) on the left hand side, and increased profit (P+) and reduced cost (C-) on the right hand side of the table. It is clear that establishment cost of *Opuntia* is the main component of cost increase, estimated at US$220/ha. Foregone opportunities in the form of selling durum wheat grain, straw and stubble are estimated at US$1086/ha. Sale of *Opuntia* is the main source of increased profit (US$2,500/ha), whereas decreased cost is estimated at US$617/ha. It is clear that an increased profit of US$3,133/ha is above the increased cost of US$1,330/ha by nearly US$1,803/ha, supporting the profitability of *Opuntia*. These calculations are based on the assumption of selling all *Opuntia* fruits at the market price, which is the case in normal weather conditions. However, under drought conditions, farmers' need for feed increased dramatically, and, thus, most of the *Opuntia* was used to feed animals. Under these conditions, nearly 40% of *Opuntia* fruit was sold (Table 3.2). The only change in the calculations is the value of increased profit, which is now US$1000/ha assuming 40% of the fruits were sold. Even in such situation, comparison between the cost and profit revealed an increase in income by US$303/ha resulting from the *Opuntia* plantation. This further supports the profitability of this production system when compared to the conventional system of durum wheat farming.

Table 3.1 **Benefits of the *Opuntia* system when all the fruits are harvested and marketed**

Details	AD	US$*	Details	AD	US$*
New charges (C+) Culture of Opuntia			*New products (P+) Culture of Opuntia*		
Installation costs (plantation, fertilization, irrigation)	16,500	220	Fruit sales (250,000 fruits/ha x 0.75DA)	187,500	2500
Maintenance (600 DA/an X 3 years)	1800	24	Racket sale (40% product) (3,5qx/ha x 840DA/ql)	1176	16
S/Total new loads (C+)	18,300	244	S/Total produced new (P+)	188, 676	2516
Old products (P-) durum wheat crop			*Old charges (C-) durum wheat crop*		
Grain sale (6qx/ha x 3 years x 3,000DA/ql)	54,000	720	Seeds (1,3qx/ha x 3 years x 2,500DA/ql)	9750	130
Sale of straw (14,4qx/ha x 3 years x 600DA/ql)	25,920	346	Mechanization (plowing, sowing, harvesting, straw collecting) 1,800 DA + 1,200 DA + 8,100 DA + 1,800 DA	12,900	172
Stubble sale (1ha x 3 years x 500DA/ha)	1500	20	Labor (driver + casual) 1,148 DA + 22,500 DA	23,648	315
S/Total old products (P-)	81,420	1086	S/Total old charges (C-)	46,298	617
Total against [(C+) + (P-)]	99,720	1330	Total for [(P+)+(C-)]	234,974	3133
Positive balance	135,254	1803	Negative balance		

US$1 = 75DA

Adoption of *Opuntia* Technology

General appreciation data

The number of farms and their distribution according to the agro-ecological zones are as follows:

Number of farms in Sidi-Fredj community	270
Total agricultural area	4586ha
Total cropped area	3886ha

Through agro-ecological and climatic characterization, three zones were identified based on farming systems and farm size (in ha) (Table 3.3).

Table 3.2 **Benefits of the *Opuntia* system when 40% of the fruits are harvested and marketed**

Details	AD	US$*	Details	AD	US$*
New expenses (C+) Culture of Opuntia			*New products (P+) Culture of Opuntia*		
Installation cost (plantation, fertilization, irrigation)	16,500	220	Fruit sale (100,000 fruits/ha x 0.75DA)	75,000	1000
Maintenance (600DA/ha x 3 years)	1800	24	Racket sales (40% production) (3,5qx/ha x 840DA/ql)	1176	16
S/Total new expenses (C+)	18,300	244	S/Total new products (P+)	76,176	1016
Old products (P-) durum wheat crop			*Old charges (C-) durum wheat crop*		
Grain sales (6qx/ha x 3 years x 3,000DA/ql)	54,000	720	Seeds (1,3qx/ha x 3 years x 2,500DA/ql)	9750	130
Straw sales (14,4qx/ha x 3 years x 600DA/ql)	25,920	346	Mechanization (plowing, sowing, harvesting, balling) 1,800 DA + 1,200 DA + 8,100 DA + 1,800 DA	12,900	172
Stubble sale (1ha x 3 years x 500DA/ha)	1500	20	Labor (driver + casual) 1,148DA + 22,500DA	23,648	315
S/Total old products (P-)	81,420	1086	S/Total old charges (C-)	46,298	612
Total against [(C+) + (P-)]	99,720	1330	Total for [(P+)+(C-)]	122,474	1633
Positive balance	22,754	303	Negative balance		

** US$1 = 75DA*

Table 3.3 **Distribution of farms according to agro-ecological zones**

Farm type	Zone 1	Zone 2	Zone 3	Total
1	71	64	42	177
2	19	56	18	93
Total	90	120	60	270

Zone 1 offers best opportunities for the diversification of agricultural activities. An important hydrographic network crosses the area (1316.5ha).

Zone 2 has very low agronomic potential due to severe degradation (2580.5ha with 200ha of rangeland).

Zone 3 is the area with least potential. It has the lowest soil fertility (1101ha with 500ha of rangeland).

Table 3.4 provides information on the adoption of *Opuntia* by farmers. The new technology was adopted by 40% of farmers, who allocated nearly 33% of their lands to *Opuntia* plantation. The adoption rate (percentage of farmers adopting the technology) and degree of adoption (percentage area planted to *Opuntia*) varied according to agro-ecological zones and farm types. The highest degree of adoption (53%) was achieved in the zone with high potential for diversification (Zone 1). The adoption degree was calculated at 24% and 29% in the zones with severe water erosion (Zone 3) and lowest soil fertility (Zone 3) respectively. *Opuntia* plantation of in such areas would contribute to land restoration and, hence, halt desertification.

Table 3.4 **Rate, degree and intensity of adoption by zone, type and community**

Designation		**Zone 1**			**Zone 2**			**Zone 3**			**Total**
		T1	**T2**	**Total**	**T1**	**T2**	**Total**	**T1**	**T2**	**Total**	
Option No. 1 – initial cropping plan											
	Barley		19	19		56	56		18	18	93
	Wheat	202	35	237	185	107	292	120	69	153	682
	Opuntia										
	Total	202	54	256	185	163	348	120	87	171	775
Acreage	Wheat	561	150	711	1011	885	1896	615	264	879	3486
	Barley		48	48		280	280		72	72	400
	Opuntia										
	Total	561	198	759	1011	1165	2176	615	336	951	3886
Option No. 1 – alternative cropping plan											
Number of farms	Total	202	54	256	185	163	348	120	87	171	775
	Barley	–	19	19	–	56	56	–	18	18	93
	Wheat	202	35	237	185	107	292	120	69	153	682
	*Opuntia**	71	19	90	64	56	120	42	18	60	270
Acreage	Wheat	355	95	450	640	560	1200	420	135	555	2205
	Barley		48	48		280	280		72	72	400
	Opuntia	453	100	553	332	142	474	136	119	255	1282
	Total	808	243	1051	972	982	1954	556	326	882	3887
Adoption rate (%)		35	54	38	34	52	41	35	26	39	40

* *The Opuntia farms are already included among the distribution of wheat farms (270 out of 682).*
T1 = farm type 1; T2 = farm type 2; Zone 1 = has potential for diversification
Zone 2 = subject to severe water erosion; Zone 3 = hills, with lowest soil fertility

Impact of *Opuntia* Technology

The impact of *Opuntia* technology was calculated using the internal rate of profitability (IRR) for 15 years. The results are presented in Tables 4.5, 4.6 and 4.7.

Calculation of IRR was done as follows:

- Calculation of the costs and benefits of *Opuntia* and wheat
- Synthesis of expenditure and incomes for *Opuntia*
- Synthesis of expenditure and incomes for wheat
- Production and prices of *Opuntia* + economic calculations (Option Nos. 1and 2)
- Production and prices of wheat + economic calculations

Table 3.5 presents costs and benefits of cactus plantation under the assumption of selling total fruit production (assumption 1). The calculated internal rate of returns (IRR) was estimated at 99%, clearly indicating the profitability of cactus plantation in Algeria. Under the assumption that fruit production and marketing was reduced to 53% of its full capacity (assumption 2, Table 3.6) due to production risks, the calculated IRR was 71%, which is above the interest rate of borrowing money from commercial banks. This high IRR supports the profitability of cactus plantation even under low levels of fruit production. The estimates explain the wide adoption of *Opuntia* to replace durum wheat plantation, which was not a feasible enterprise. The costs of wheat production was twice as high as its benefits, resulting in negative IRR (Table 3.7), indicating that wheat production was not profitable.

Table 3.5 **Calculation on net economic values of cactus production (simulation for 15 years at 10%) — Option 1**

Year	Fruit yield (unit/ ha)	Fruit price (US$/ unit)	Fruit benefit (US$/ ha)	Feed yield (t/ha)	Feed price (US$/t)	Feed benefit (US$/ ha)	Total benefit (US$/ ha)	Discount factoR (@10%)	Actual benefit (US$)	Total cost cactus (US$)	Actual coef. (@10%)	Discounted cost (US$)	Net discounted benefit
1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.909	0.00	339.50	1.100	308.64	-308.64
2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.826	0.00	44.00	1.210	36.36	-36.36
3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.751	0.00	44.00	1.331	33.06	-33.06
4	165,000	0.01	1650.00	1.59	112.00	178.08	1828.08	0.683	1248.58	27.84	1.464	19.02	1229.56
5	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.621	1566.73	30.40	1.611	18.88	1547.86
6	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.564	1422.93	30.40	1.772	17.16	1405.77
7	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.513	1294.26	30.40	1.949	15.60	1278.66
8	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.467	1178.20	30.40	2.144	14.18	1164.02
9	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.424	1069.72	30.40	2.358	12.89	1056.83
10	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.386	973.85	30.40	2.594	11.72	962.13
11	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.350	883.02	30.40	2.853	10.66	872.37
12	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.319	804.81	30.40	3.138	9.69	795.13
13	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.290	731.65	30.40	3.452	8.81	722.84
14	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.263	663.53	30.40	3.797	8.01	655.52
15	222,500	0.01	2225.00	2.66	112.00	297.92	2522.92	0.239	602.98	30.40	4.177	7.28	595.70
							Benefit value:		**12,440.25**		**Cost value:**	**531.93**	**11,908.32**
							Benefit/cost ratio:		**23.39**			**IRR:**	**99%**

Table 3.6 **Calculation on net economic values of cactus production (simulation for 15 years at 10%) — Option 2**

Year	Fruit yield (unit/ha)	Fruit price (US$/unit)	Fruit benefit (US$/ha)	Feed yield (t/ha)	Feed price (US$/t)	Feed benefit (US$/ha)	Total benefit (US$/ha)	Discount factoR (@10%)	Actual benefit (US$)	Total cost cactus (US$)	Actual coef. (@10%)	Discounted cost (US$)	Net discounted benefit
1	0	0.00	0.00	0.00	0.00	0.00	0.00	0.909	0.00	339.50	1.100	308.64	-308.64
2	0	0.00	0.00	0.00	0.00	0.00	0.00	0.826	0.00	44.00	1.210	36.36	-36.36
3	0	0.00	0.00	0.00	0.00	0.00	0.00	0.751	0.00	44.00	1.331	33.06	-33.06
4	70,500	0.01	705.00	1.59	112.00	178.08	883.08	0.683	603.14	27.84	1.464	19.02	584.13
5	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.621	914.68	30.40	1.611	18.88	895.81
6	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.564	830.73	30.40	1.772	17.16	813.57
7	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.513	755.61	30.40	1.949	15.60	740.01
8	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.467	687.85	30.40	2.144	14.18	673.67
9	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.424	624.52	30.40	2.358	12.89	611.63
10	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.386	568.55	30.40	2.594	11.72	556.83
11	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.350	515.52	30.40	2.853	10.66	504.87
12	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.319	469.86	30.40	3.138	9.69	460.18
13	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.290	427.15	30.40	3.452	8.81	418.34
14	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.263	387.38	30.40	3.797	8.01	379.37
15	117,500	0.01	1175.00	2.66	112.00	297.92	1472.92	0.239	352.03	30.40	4.177	7.28	344.75
							Benefit value:		**7137.02**		**Cost value:**	**531.93**	**6605.08**
							Benefit/cost ratio:		**13.42**			**IRR:**	**71%**

Table 3.7 **Calculation of net economic values of wheat production (simulation for 15 years at 10%)**

Year	Grain yield (t/ha)	Grain price (US$/ t)	Grain benefit (US$/ ha)	Straw yield (t/ha)	Straw price (US$/t)	Straw benefit (US$/ ha)	Total benefit (US$/ ha)	Discount factor (@10%)	Actual benefit (US$)	Total cost wheat (US$)	Discount factor (@10%)	Discounted cost (US$)	Net discounted benefit
1	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.909	122.76	195.00	0.909	177.26	-54.49
2	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.826	111.55	195.00	0.826	161.07	-49.52
3	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.751	101.42	195.00	0.751	146.45	-45.02
4	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.683	92.24	195.00	0.683	133.19	-40.95
5	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.621	83.87	195.00	0.621	121.10	-37.23
6	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.564	76.17	195.00	0.564	109.98	-33.81
7	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.513	69.28	195.00	0.513	100.04	-30.75
8	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.467	63.07	195.00	0.467	91.07	-28.00
9	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.424	57.26	214.50	0.424	90.95	-33.69
10	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.386	52.13	214.50	0.386	82.80	-30.67
11	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.350	47.27	214.50	0.350	75.08	-27.81
12	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.319	43.08	214.50	0.319	68.43	-25.34
13	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.290	39.16	214.50	0.290	62.21	-23.04
14	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.263	35.52	214.50	0.263	56.41	-20.90
15	0.32	293.30	93.86	0.77	53.50	41.20	135.05	0.239	32.28	214.50	0.239	51.27	-18.99
							Benefit value:		**3061.50**		**Cost value:**	**1527.26**	**-500.20**
							Benefit/cost ratio:		**2.00**			**IRR:**	**Negative**

Introduction of the "Ram Effect" Technology

Farms in Sidi-Fredj and Mtoussa are characterized by a permanent presence of males in herds. This results in a fall in the fertility rate of the ewes and a random distribution of births throughout the year, which causes high mortality rates among the lambs, especially those born during winter and summer. There is, therefore, a need to develop technologies that would address these issues. One of the most adopted practices is a rigorous management of reproduction by the adoption of a technology known as the "ram effect." the Technical Institute of Breeding (ITELV) in Aïn-M'lila area conducted a study of this practice on ten farms.

Principal Characteristics of the Technology

The technology involves isolating males from the herd one month before the beginning of the fight and re-introduced throughout fight. The objectives are, on the one hand, to control the date of reproduction (choice of the best moment of the fertility and fruitfulness of the ewe, determination of the best period of the births), and, on the other, to support the induction of ovulation, synchronize the fight, and consequently time the births during the periods of fodder abundance. This is in addition to the "flushing technique," which aims to improve the prolificacy of the ewe by providing additional food (200g of barley/day for one month, and even after) to reduce embryonic losses.

Implementation and Diffusion of the Technology

The process of diffusion of the ram effect technology included:

- Organizing events to sensitize farmers on the method through a series of presentations on the technology, e.g., the method of induction and synchronization of heat in small ruminants.

Of the 70 stockbreeders present, 18 expressed interest in immediately applying the suggested technology

- Implementing the method with 18 interested stockbreeders:
    - isolation of the males and olfactive, auditive and visual isolation for one month
    - application of the flushing
    - handing over of the rams in the herd after one month of minimum isolation

Stockbreeders who subscribed to the technique were about 13, for an evaluated number of 610 ewes

Results Obtained after Diffusion

Of the 364 ewes put at the fight within the framework of the application of this technology, 277 (76%) produced 325 lambs, giving 117.5% rate of prolificacy. The following were observed:

- Very early births (average 1.5 months) and grouped lambing
- A fertility rate of 89–94%, which normally was 77–83% in an intensive system and 60% in an extensive system
- A twining rate (birth of twins) of 25–35%, instead of about 2.5%
- A death rate of 6.2% in young lambs aged 0–3 months, against 18–20% on average in the zone

Impact Study of the "Ram Effect" Technology

The impact of the "ram effect" technology was determined by calculating the IRR simulated for seven years. It included the following elements:

- Calculation of the costs and benefits of the ram effect in comparison with traditional practices
- Synthesis of expenditure and receipts for the ram effect practice
- Synthesis of the expenditure and receipts of traditional practices
- The production table and prices of ram effect + economic calculations
- The production table and prices of traditional practices + economic calculations

The ram effect practice showed a high IRR (393%). The performance of ewes exposed to improved rams is presented in Table 3.8. The calculations are based on 118% lambing percentage and a mortality rate of 6%. As a result, the calculated B/C ratio is 1.51 and the corresponding IRR is estimated at 393%, supporting the high profitability of improved ram technology. Under current farmer practice, the lambing percentage is 87% and the mortality rate is 2%. A comparison of the benefits and costs of traditional technology (Table 3.9) results in a B/C ratio of 0.98 and an IRR of 17%. The calculated IRR of traditional technology is well below that of improved ram technology (393%), which clearly justifies adoption of the improved rams.

Table 3.8 **Calculation of ram effect technology on net economic values (simulation for 7 years at 10%) (Option 1: Improved technology)**

Year	Number of ewes (head)	Produced lambs (head)	Dead lambs (head)	Meat prod. (t)	Meat price (US$/t)	Meat benefit (US$)	Discount factor (@10%)	Actual benefit (US$)	Total cost meat prod. (US$)	Discount factor (@10%)	Discounted meat cost (US$)	Net discounted benefit
0	0	0	0	0	2160.00	0.00	1.000	0.00	8,667.00	1.000	8,667.00	-8,667.00
1	1050	1236	76	43	2160.00	92,448.00	0.909	84,035.23	54,075.00	0.909	49,154.18	34,881.06
2	1050	1236	76	43	2160.00	92,448.00	0.826	76,362.05	54,075.00	0.826	44,665.95	31,696.10
3	1050	1236	76	43	2160.00	92,448.00	0.751	69,428.45	54,075.00	0.751	40,610.33	28,818.12
4	1050	1236	76	43	2160.00	92,448.00	0.683	63,141.98	54,075.00	0.683	36,933.23	26,208.76
5	1050	1236	76	43	2160.00	92,448.00	0.621	57,410.21	54,075.00	0.621	33,580.58	23,829.63
6	1050	742	46	26	2160.00	55,512.00	0.564	31,308.77	54,075.00	0.564	30,498.30	810.47
7	1050	742	46	26	2160.00	55,512.00	0.513	28,477.66	54,075.00	0.513	27,740.48	737.18
							Benefit value:	**410,164.34**		**Cost value:**	**271,850.03**	**138,314.32**
							Benefit/cost ratio:	**1.51**			**IRR:**	**393%**

Table 3.9 **Calculation of net economic values of ram effect technology (simulation for 7 years at 10%) (Option 2: Traditional technology)**

Year	Number of ewes (head)	Produced lambs (head)	Dead lambs (head)	Meat prod. (t)	Meat price (US$/t)	Meat benefit (US$)	Discount factor (@10%)	Actual benefit (US$)	Total cost meat prod. (US$)	Discount factor (@10%)	Discounted meat cost (US$)	Net discounted benefit
0	0	0	0	0	2160.00	0.00	1.000	0.00	8,400.00	1.000	8,667.00	-8400.00
1	1050	913	18.6	27.9	2160.00	60,264.00	0.909	54,779.98	54,075.00	0.909	49,154.18	5625.80
2	1050	913	18.6	27.9	2160.00	60,264.00	0.826	49,778.06	54,075.00	0.826	44,665.95	5112.11
3	1050	913	18.6	27.9	2160.00	60,264.00	0.751	45,258.26	54,075.00	0.751	40,610.33	4647.94
4	1050	913	18.6	27.9	2160.00	60,264.00	0.683	41,160.31	54,075.00	0.683	36,933.23	4227.09
5	1050	913	18.6	27.9	2160.00	60,264.00	0.621	37,423.94	54,075.00	0.621	33,580.58	3843.37
6	1050	548	43.8	16.7	2160.00	36,072.00	0.564	20,344.61	54,075.00	0.564	30,498.30	-10,153.69
7	1050	548	43.8	16.7	2160.00	36,072.00	0.513	18,504.94	54,075.00	0.513	27,740.48	-9235.54
							Benefit value:	**267,250.10**		**Cost value:**	**271,583.03**	**-4332.92**
							Benefit/cost ratio:	**0.98**			**IRR:**	**17%**

NB: Other parameters are identical to those of the technological option, except the additional food costs.

4

Adoption and Impact Studies in Iraq

4.1 The Impact of Barley Varietal Technology in Iraq[1]

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Introduction

Nearly 48% of barley produced in Iraq in the last four decades was grown in rainfed conditions, but the yield was very low, between 400 and 800kg/ha. These low yield levels contribute directly to feed deficits, although there is great capacity for higher domestic agricultural production through greater efficiency.

Research suggests that individual characteristics influence observed adoption decisions (Deuson and Day, 1990; Jarvis, 1981; Kebede et al, 1990; Sarap and Vashist, 1994), and that the use of information on the relationship between these characteristics and observed behavior can influence adoption policies. Technology adoption research in Iraq shows that farm size and profitability, among others, are the most significant factors affecting the three indicators of adoption ¯ adoption rate, degree of adoption and intensity of adoption (Shideed, 1997).

Agricultural output could be increased through greater productivity of farm inputs. Productivity (output per unit of all inputs) measures the technical efficiency with which resources are converted to commodities (Lu, Cline and Quance, 1979). Increased agricultural productivity enables a farmer to produce more with the same amount of resources.

Although many factors contribute to agricultural productivity, technology is the most important of all in the long term. However, to affect productivity, technology must be adopted in the production processes. The rate of adoption of a new technology is largely subject to its profitability, degree of risk associated with it, capital requirements, agricultural policies, and socioeconomic characteristics of farmers.

New technology adoption is an important source of productivity gains in various production systems. Producers benefit from the adoption of new technology through opportunities to lower production costs, either by increasing outputs from the same inputs or by maintaining the same output from reduced inputs (Griffith et al, 1995).

One of the short-term impacts of a new agricultural technology is an increase in the income of farmers adopting the technology. However, the important aspect is the effect of adoption on the pattern of income distribution among them. Previous studies have attempted to measure farm income inequality and isolate and meas-

[1] The research was completed when the senior author was a Professor and Head, Department of Planning and Economic Analysis at IPA Agricultural Research Center, Baghdad, Iraq

ure the net effect of new technology on farm income distribution (Raju, 1979). The central issue here is the tradeoff between more income and an equal distribution of income. The impact of modern crop varieties on productivity is transmitted into higher land prices. Because of the environmental specificity of improved varieties, land prices increase most in irrigated areas and less in rainfed areas (Jatileksono and Keijiro, 1993). The widening productivity differential between favorable and unfavorable production environments may lead to regional income distribution. However, recent studies have found that although the adoption of improved varieties increased labor demand and, hence, wages in favorable areas in the short term, interregional migration from unfavorable to favorable areas reduced the regional wage differential in the long term. Therefore, the regional difference in labor income may not be as large as the regional productivity differential suggests. More investigation is needed to compare overall income and productivity gains with more equal distribution of gains across production environments.

New crop varieties, like any other new technology, may change the optimal levels of inputs used. The profitability of adopting new varieties will depend on how the demands for inputs are changed and how large the productivity improvement is (Lin, 1994). Thus, an understanding of the effect of new varieties on input demand and productivity is crucial for better understanding of potential diffusion of the technology among farmers. Results indicate that technology change in wheat production, for example, has been cost-saving and is neither strongly biased in a labor-saving nor a capital-saving direction (Sidhu, 1974).

Widespread adoption of new production technology may also have important market effects. The adoption rate for a new livestock production technology, for example, was shown to have a major effect on market prices and quantities following its introduction (Griffith et al, 1995). In *ex-ante* analyses, adoption rates are often expressed in terms of either the number of producers expected to use the technology or the number of animals affected by it. Adoption rates may be difficult to estimate since adoption is itself endogenous, depending on the technology's profit-time path and producers' profit expectations. Thus, widespread adoption of a new technology is likely to have economic implications beyond the production system. An integrated economic model incorporating both production and marketing systems is, therefore, required to assess accurately its impacts. Farm level models are necessary to establish the output and revenue changes from the technology. Industry supply responses can then be estimated by aggregating the farm responses under an assumed industry adoption level.

The collaborative research activities between the Iraqi National Agricultural Research System and ICARDA have resulted in introducing several improved barley and sheep production technologies into the farming system of Iraq. With the impressive adoption rates of these technologies, as was evident from technology adoption surveys, there is a need to quantify the impact of new technologies at the farm and national levels. The main purpose of this study was to assess the impact of improved barley cultivar 'Rihan 03' on barley production in Iraq.

Impact of Improved Barley Cultivar on Productivity

New crop varieties, like any other new technology, may change the optimal levels of inputs used. The profitability of adoption of new varieties will depend on how the demands for inputs are changed and how large the productivity improvement is (Lin, 1994). Thus, an understanding of the effect of new varieties on input demand and productivity is crucial for a better understanding of the potential diffusion of the technology among farmers. A new technology will not be acceptable to farmers unless it raises productivity. In this study, an we attempted to examine to what extent productivity increased by the introduction of improved barley cultivar 'Rihan 03'.

A cross-sectional survey of 495 barley farmers was conducted in the summer of 1996. The survey collected detailed information on land use, input applications, and output of improved and local cultivars. Among the sample, 210 farmers produced only improved cultivars, 208 grew only local cultivars and 77 planted both the improved and local cultivars. Observations in the data set were made according to the cultivar and farmer. That is, there were two observations for a farmer who planted both improved and local cultivars, making the total number of observations in the data set 572.

Results show that the average yield of 'Rihan 03' was 1.124t/ha, higher than that of local barley cultivar (0.788t/ha) by about 43%. However, because more chemical fertilizers were used in the production of the improved variety, it is difficult to decide whether the yield advantage of improved cultivar simply reflects the impact of chemical fertilizer application or technical properties of 'Rihan 03'.

Productivity (output quantity per unit of input) is usually measured by index numbers. However, index numbers impose restrictions on the form of the underlying production function, priori. The Laspeyrex index, for example, assumes that the production function is linear, implying perfect substitution among all inputs in the production process. To avoid this restrictive assumption, Ball (1985) derived revised indexes for productivity from a flexible multi-output multi-input representation of the production function of the form translog transformation function.

However, the translog function is constrained to constant return to scale. This is a restrictive assumption that lacks empirical evidence to be imposed a priori on barley production in Iraq. Moreover, the multicolinearity problem among variable inputs is always evident in the translog function. As a result, it gives lower values for the estimates of the t-test for many variables in the function. These two difficulties may discourage the use of the index number approach for studying the impact of varietal technology on total factor productivity. Instead, a frequently used method for estimating is the Cobb-Douglas function approach, due to its ease of estimation and interpretation (Lin, 1994).

An appropriate technique for determining the impact of 'Rihan 03' technology on productivity is the regression analysis. A Cobb-Douglas production function was identified and estimated. The impact of the improved barley cultivar on the total factor productivity was estimated by adding a dummy variable to the function.

The estimated production function is assumed to have the following form (Shideed and Saleem, 1998):

$$\text{Ln } Q = B_0 + B_1 \text{ Ln } X_1 + B_2 \text{ Ln } X_2 + B_3 \text{ Ln } X_3 + B_4 \text{ Ln } X_4 + B_5 \text{ Ln } X_5 + B_6 \text{ Ln } X_6 + B_7 \text{ Ln } X_7 + B_8 \, DVAR_1 + V$$

Where: Q = barley output (tons)
Bi's = parameters to be estimated
X_1 = planted area (hectare)
X_2 = total amount of seed (kg)
X_3 = total amount of fertilizers (kg)
X_4 = machinery (hours)
X_5 = labor (hours)
X_6 = education measure in numbers of years of formal schooling
X_7 = farmer's age (years)
$DVAR_1$ = dummy variable for the improved cultivar 'Rihan 03'
V = a residual term to capture the effect of other variables not directly included in the model

Before analyzing the impact of the improved barley cultivar on productivity, it is important to determine whether the technological change attributed to the introduction of 'Rihan 03' is of neutral type or not. To do so, separate production functions for the improved and local cultivars were estimated and compared with a pooled function, as shown in Table 4.1. To test the hypothesis of a neutral technical change, an F statistic was calculated based on chow test as follows (Kennedy, 1985):

$$F^* = \frac{[SSE\text{ (constrained)} - SSE\text{ (unconstrained)}]/K}{SSE\text{ (unconstrained)}/(T_1 + T_2 - 2K)}$$

Where: SSE = error sum of squares
K = number of estimated parameters including the intercept
T_1 = number of observations for the regression equation of improved cultivar
T_2 = number of observations for the regression equation of local cultivar
SSE (unconstrained) = sum of error sum of squares for the regression equations of improved and local cultivars

SSE (constrained) = error sum of squares for the pooled regression equation

The estimated F* value is 3.72 for (9, 554) degrees of freedom, which is not significant at 99% (μ = 0.01) level of significance.

Table 4.1 **Estimated production functions for improved and local barley cultivars**

Independent variables	Local cultivar	Improved cultivar	Pooled regression
Intercept	0.349	0.752	0.844*
	(0.556)	(0.261)	(1.821)
Ln Land (ha)	0.083	0.554**	0.201*
	(0.598)	(3.599)	(1.988)
Ln Seed (kg)	0.719**	0.521**	0.714**
	(5.517)	(3.482)	(7.237)
Ln Labor (hr)	0.077*	-0.019	0.033
	(1.773)	(-0.450)	(1.054)
Ln Machinery (hr)	0.135**	-0.035	0.055
	(2.474)	(-0.680)	(1.458)
Ln Fertilizers (kg)	0.0172**	0.014**	0.0219**
	(5.30)	(1.979)	(7.27)
Ln Farmer's age (year)	0.008	-0.0859	-0.038
	(0.081)	(-0.794)	(-0.509)
Ln Education (year)	-0.012	-0.045	-0.015
	(-0.353)	(-1.279)	(-0.609)
Size (0,1)	0.077	-0.067	0.021
	(0.877)	(-0.777)	(0.337)
N	285	287	572
R^{-2}	0.96	0.92	0.94
D-W test	1.857	1.43	1.64
F test	892.72**	431.38**	1183.78**

Numbers in parenthesis refer to t-test
**, ** significant at 5% and 1% level of significance respectively*

Therefore, we cannot reject the hypothesis that output elasticities with respect to various inputs are the same in separate regressions for local and improved barley cultivars if the constant term in the two regressions are allowed to differ. This supports the hypothesis of neutral technical change, meaning that varietal technological change of barley production is not strongly biased in either a laborsaving or capital-saving direction. Similar results were obtained for new wheat varieties in India (Sidhu, 1974).

We concluded that we can study the impact of the improved cultivar on factor productivity by estimating a pooled production function for both improved and local cultivars. The impact on productivity can be measured by including a dummy variable into the production function, taking a value of one for improved cultivar and zero for the local variety. The production function was estimated using OLS procedure and the estimated coefficients are presented in Table 4.2. The value of R-2 indicates that the explanatory variables included in the model explain 94% of total variation in barley production. The variables of land, seed and fertilizers are having more effect on barley production and their estimated coefficients are significant at 1% level. None of the potential econometric problems of multicolinearity, autocorrelation and heteroscedasticity was found to be of harmful nature.

Table 4.2 **Estimated coefficients of the barley production function (n = 572)**

Independent variables	Function (1)	Function (2)
Intercept	0.419	-0.110
	(0.898)	(-0.235)
Ln Land (ha)	0.339**	0.417**
	(3.238)	(4.030)
Ln Seed (kg)	0.607**	0.536**
	(6.055)	(5.408)
Ln labor (hr)	0.029	0.037
	(0.958)	(1.238)
Ln Machinery (hr)	0.034	0.045
	(0.914)	(1.227)
Ln Fertilizers (kg)	0.0178**	0.0176**
	(5.678)	(5.759)
Ln Farmer's Age (year)	-0.030	-0.025
	(-0.411)	(-0.341)
Ln Education (year)	-0.022	-0.028
	(-0.896)	(-1.155)
Dummy - Size	0.0053	0.0125
	(0.085)	(0.208)
Dummy-'Rihan 03'	0.166**	
	(4.306)	
Dummy ('Rihan 03' * MRA)		0.3559**
		(6.064)
Dummy ('Rihan 03' * LRA)		0.117*
		(1.75)
Dummy (Local * MRA)		0.154**
		(2.81)
R^2	0.94	0.95
D-W test	1.65	1.73
F test	1087.1**	932.2**

Number in parenthesis refers to calculated t-test.
**, ** significant at 5% and 1% levels respectively.*

The estimated coefficient of the dummy variable measures the shift in the intercept of the production function as a result of the improved barley cultivar. The shift captures the impact of 'Rihan 03' on total factor productivity. From the estimated coefficient of 0.166 of the improved cultivar dummy (function 1), we can conclude that the total factor productivity of the improved cultivar was about 19% higher than that of the local barley cultivar. That is, given the same level of inputs, the yield advantage of the improved variety over the conventional variety was about 19%. This is the magnitude of the neutral upward shift in the barley production function resulting from the introduction of 'Rihan 03'. Since the shift in the production function is of neutral type, it implies that the improved cultivar gives a higher output per unit input than the local variety.

The estimates provide other important information about barley production under rainfed conditions. Seed is the predominant factor in barley production. A 10% increase in seeding rate will result in a 6.1% increase in barley production, holding other inputs constant. Similarly, a 10% increase in the planted area will result in a 3.4% increase in barley output. The sum of the coefficients of land, seed, fertilizers, machinery, and labor is 1.027, which is close to one. This implies that barley production has a constant return to scale. Therefore, large farm size does not have a positive effect on productivity in barley production areas.

Actual yield comparison from sample farms showed that yield levels of both improved and local cultivars vary with respect to rainfall zone. This means that the impact of improved cultivar on factor productivity will vary with respect to the rainfall zone. To study this impact, the production function was re-estimated (function 2) by adding three dummy variables. The dummy variables are Rihan 03 *MRA, Rihan 03 *LRA, and Local *MRA. The first dummy, Rihan 03 *MRA, measures the impact of the improved cultivar on factor productivity, compared to the local variety in the moderate rainfall area. The second dummy, Rihan 03 *LRA, reflects the impact of improved cultivar in the limited rainfall area in comparison to the local variety. Whereas the third variable, Local *MRA, measures the impact of the MRA in increasing the productivity of the local cultivar in comparison to the LRA.

From the estimated coefficients of these dummy variables, it is clear that the improved cultivar increased factor productivity by 43% in the MRA compared to the local variety, whereas the productivity of the improved cultivar was greater than that of the local cultivar by only 12% in the LRA. Meanwhile, the productivity of the local variety in the MRA was higher than its productivity in the LRA by about 17%. These increases in total factor productivity reflect the technical properties of the improved cultivar, which was lower than the combined impact of the cultivar and fertilizers, as shown in general yield comparisons. The yield of ‘Rihan 03’ in the MRA of 1224.8kg/ha was greater than that of the local variety of 731.6kg/ha by about 67.4%. Whereas the yield of the improved cultivar of 902kg/ha in the LRA exceeded that of the local variety of 706.4kg/ha by about 28%.

Impact of Improved Barley Cultivar on Factor Demands

Model specification and estimation

To study the impact of the improved cultivar on supply of barley and the demand for variable inputs, it is important to first derive the factor demand and output supply functions. For this purpose, an indirect profit function within the framework of duality theory is specified. Previous studies suggest that in the study of production using farm level data, the application of normalized restricted profit function and factor demand functions is a more reasonable and less problematic approach (Sidhu and Baanante, 1979 and 1981). Such an approach overcomes many of the problems associated with direct estimation of production and demand functions.

The concept of normalized production function is more appropriate than the production function for empirical analysis of short-term production decisions for at least two reasons (Sidhu and Baanante, 1979). First, the normalized profit function is a function only of predetermined variables and, thus, econometrically more appropriate for estimation. Second, the system of input demand and output supply functions derived from the normalized restricted profit function facilitates interpretation and analysis for deriving policy implications.

Assume that the barley production function for farmers of Ninavah province is specified as:

$$Y = f\ (S, F, M, N; L, E, DV1) \qquad (1)$$

Where: Y = total output of barley (ton)
S, F, M and N = variable inputs of seed, fertilizer, machinery, and labor respectively
L and E = fixed factors of land and education respectively
DV1 = varietal dummy variable taking the value of 1 for the improved cultivar and zero for the improved cultivar and zero for the local variety.

For the specified production function (1), there is a corresponding normalized restricted profit function. Per farm restricted profit p, is defined as total revenue from barley less total variable costs, and after normalization by the price of barley P is expressed as a function of the normalized prices of the variable inputs of seed, fertilizer, machinery and labor, and the quantities of the fixed inputs of land and education, as follows (Sidhu and Baanante, 1979):

$$\pi^* = \frac{\pi}{P} = f\ (Pi; L1, E, DV_1), \qquad i = S, F, M, N \qquad (2)$$

Where Pi is the normalized price of variable inputs. Demand functions for the variable factors of seed, fertilizer, machinery and labor are obtained by differentiating the normalized profit function with respect to the respective normalized input prices:

$$X_i^* = \frac{\partial \pi^*}{\partial Pi}, \qquad i = S, F, M, N \qquad (3)$$

Where X_i^* refers to the quantity of input i.

Under the assumption that the production function (1) is of Cobb-Douglas form, the 'estimatable' equations in (2) and (3) can be specified as:

$$\begin{aligned} Ln\ \pi^* &= Ln\ A + B_1\ Ln\ P_s + B_2\ Ln\ P_f + B_3\ Ln\ P_m + B_4\ Ln\ P_n \\ &+ B_5\ Ln\ Age + B_6\ Ln\ E + B_7\ Ln\ L + B_8\ DL + B_9\ DV_1 \end{aligned} \qquad (4)$$

Where: Age = the farmer's age (years)
DL = dummy variable to measure the impact of farm size, taking the value 1 if the farm size is ≤ 25 hectares and 0 if it is < 25 hectares[2].

$$- \frac{P_s.S}{\pi^*} = B + A_2\ DV_1 \qquad (5)$$

$$- \frac{P_f.F}{\pi^*} = S_0 + S_2\ DV_1 \qquad (6)$$

$$- \frac{P_m.M}{\pi^*} = D_0 + D_2\ DV_1 \qquad (7)$$

$$- \frac{P_n.N}{\pi^*} = E_0 + E_2\ DV_1 \qquad (8)$$

Where: Equation (4) = the normalized restricted profit function in the logarithmi form
Equations (5)–(8) = the factor share equations for seed, fertilizer, machinery, and labor
Equations (4)–(8) = a system in which the restricted profit and factor shares are a set of jointly determined variables (Sidhu and Baanante, 1979)
P_s, P_f, P_m, and Pn = the prices of seed, fertilizer, machinery, and labor, respectively

The parameters A_2, S_2, D_2, and E_2 in equations (5)–(8) are equal to their corresponding parameters in equation (4) under the assumption of profit maximization for both improved and local barley cultivars. This hypothesis of profit maximization can be tested directly by comparing this system with another one, and does not assume the equality of these parameters (unconstrained model). The dummy variable DL is added to equation (4) to compare the economic efficiency and its components of technical and price efficiency for small farms (< 25ha) and large farms (≤ 25ha). If both small and large farms have equal efficiency parameters, the dummy variable DL will be excluded from the model.

Model estimation and hypothesis testing
To complete the specification of the model, additive error terms having zero means and finite variance are assumed for each of the five equations, (4)–(8), in the model. The covariance of the error terms of any two of the equations for the

same farm may not be zero, but the covariance of the error terms of any two equations corresponding to different farms are assumed to be identically zero. This means that error terms of different equations are "contemporaneously correlated". Under these assumptions, an asymptotically efficient method of estimation is the Zellner's seemingly unrelated regression estimation procedure (SURE).

Both SURE and OLS procedures are used to estimate the specified econometric model, equations (4)–(8), using previously described farm level data.

Three statistical hypotheses are tested. The first one is the hypothesis that small and large farms have equal economic efficiency. It is tested using the following F statistic (Kennedy, 1985):

$$F^* = \frac{[SSE\ (constrained) - SSE\ (unconstrained)]/R}{SSE\ (unconstrained)/(T-K)}$$

Where: R = number of restrictions under testing, represented by the difference of estimated parameters in the constrained and unconstrained models

K = number of estimated parameters including the intercept, in the unco strained regression

T = number of observations (sample size)

SSE (constrained) = error sum of squares for constrained model, which is the model that assumes that small farms and large farms are equal with respect to economic efficiency (i.e., not including a dummy variable from farm size in the estimated model)

SSE (unconstrained) = error sum of squares for the unconstrained model, which is the model that assumes that small farms are not equal to large farms with respect to economic efficiency (i.e., having a dummy variable from farm size in the estimated model)

After estimating both constrained and unconstrained models, the F* statistic was calculated and found to be equal to 2.055. The corresponding table value for (6, 550) degrees of freedom was 2.10 for $\mu = 0.05$ and 2.80 for $\mu = 0.01$. Since calculated F* was less than its table value, we could not reject the null hypothesis, suggesting that small and large farms have equal economic efficiency. The results of this test is consistent with that of the first part, in which barley production was found to have a constant return to scale, meaning that large farms do not achieve any economies of scale compared to the small farms.

The second tested hypothesis was that estimated parameters of factor share equations are equal to their corresponding parameters in the normalized profit function. This means:

$$A2 = B1; \quad S2 = B3; \ D2 = B4; \quad E2 = B2$$

To test this hypothesis, the model was re-estimated and the value of F* was calculated using the above formula. Under this formula, SSE (constrained) represents error sum of squares for the model, which assumes that estimated parameters of variety in the factor demand equations are equal to the corresponding price parameters in the profit function. The number of constraints was equal to four for this case. SSE (unconstrained) is the error sum of squares for the model, which does not assume the equality of the parameters. The calculated F* value for this test was 9.495, which is greater than its table value of 2.37 and 3.32 for (4,556) degrees of freedom and 5% and 1% levels of significance respectively. Since the calculated F* value was greater than its table value we could not accept the hypothesis that parameters of the factor demand functions are equal to their corresponding parameters in the profit function, suggesting that the unrestricted model be adopted for this study. This implies that there is no "absolute price efficiency" associated with the adoption of the improved cultivar. Therefore, the main source of economic efficiency associated with the improved cultivar is its higher technical efficiency compared to the local cultivar. This will encourage wide adoption of the improved cultivar by farmers.

The third tested hypothesis was that estimated parameters of profit and factor demand functions are equal for both improved and local cultivars. This requires estimating pooled model using the observations of both varieties and comparing it with the unconstrained model, which includes estimating two separate models each for the improved and local cultivars. The unconstrained model assumes that price elasticities are not the same for the two cultivars. Rather, they vary with respect to the cultivar. An F statistic was estimated as follows:

$$F^* = \frac{[\text{SSE (constrained)} - \text{SSE (unconstrained)}]/K}{\text{SSE (unconstrained)}/\ (T_1 + T_2 - 2K)}$$

Where: SSE (constrained) = error sum of squares for pooled model
SSE (unconstrained) = sum of error sum of squares for the regression of the improved and local cultivars
T1 and T2 = number of observations of improved and local cultivars respetively
K = number of estimated parameters including the intercept

The calculated F* value was 0.454, whereas its table values were 1.79 and 2.25 for (11, 550) degrees of freedom and 5% and 1% levels of significance respectively. Since the calculated F* value was lower than its table value, we could not reject the null hypothesis of equal price elasticities for both improved and local cultivars. Thus, the pooled model was adopted to complete the analysis of this study.

Factor demand and output supply functions

To study the impact of 'Rihan 03' on output supply and factor demands, the final system of normalized restricted profit function and factor share equations of seed, fertilizer, machinery and labor was estimated, taking into consideration the results of tested hypotheses, by using SURE and OLS estimation methods.

The estimated equations are presented in Table 4.3. Application of Hotelling Lemma to the estimated model, the negative of the partial derivative of the profit function with respect to input price, gives factor demand function for that input. Similarly, the partial derivative of the normalized restricted profit function with respect to barley price gives the output supply function. The derived output supply and factor demand functions are presented in Table 4.4.

From these estimated input demand functions, it is possible to calculate the impact of improved barley cultivar on the demand for seed, fertilizer, machinery and labor. Data presented in Table 4.5 express the impact of 'Rihan 03' on the demand for variable inputs. It is clear that the use of the improved cultivar will increase the demand for seed by 15.6–23%, fertilizers 15.4–21.9%, machinery 20–29%, and labor 18.6–28.5%. These results are consistent with the findings of previous studies, which showed that improved technologies increase the demands for variable inputs of production. This means that the use of the improved cultivar requires higher input levels compared to the local variety. These results have important policy implications in that the supplies of seed, fertilizers, machinery and labor should be increased to the levels of new demands in order to increase the efficiency of barley production under rainfed conditions of Iraq.

Estimated own and cross price elasticities show that barley price is the most important variable affecting resource use in barley production (Table 4.6). The estimated elasticities of output supply and factor demand functions of seed, fertilizers, machinery and labor with respect to barley price demonstrated elastic response (elasticity is greater than one). Own price elasticities of factor demand functions were also elastic, whereas all cross price elasticities of demand functions were less than one (in absolute value) and smaller than own price elasticities by one. All cross price elasticities were negative, indicating a complementary relationship among production variable inputs.

Table 4.3 **Estimated parameters for profit functions and factor demand functions for variable input**

Function and variables	Estimated parameters	OLS	SURE
Profit function			
Intercept	A	-1.997	-0.688
		(-7.86)**	(-3.40)**
Ln seed price	B1	-0.339	-0.416
		(-0.88)	(-1.39)
Ln fertilizer price	B2	-0.228	-0.183
		(-1.67)	(-1.72)*
Ln machinery price	B3	-0.101	-0.125
		(-3.03)**	(-4.85)**
Ln labor price	B4	-0.114	0.123
		(-0.733)	(1.02)
Ln education	B6	-0.099	-0.086
		(-1.46)	(-1.63)
Ln area	B7	0.884	0.623
		(26.39)**	(23.90)**
Cultivar (dummy variable)	B9	0.522	0.528
		(4.06)**	(4.49)**
SSE		803.32	918.79
D - W test		1.78	1.60
R-2		0.60	0.60
Demand function for seed			
Intercept	B0	5.557	5.557
		(46.09)**	(46.17)**
Cultivar	A2	-0.259	-0.259
		(-1.52)	(-1.53)
Demand function for machinery			
Intercept	S0	3.338	3.338
		(37.07)**	(37.14)**
Cultivar	S2	-0.379	-0.379
		(-2.98)**	(-2.98)**
Demand function for labor			
Intercept	D0	0.903	0.903
		(11.89)**	(11.92)**
Cultivar	D2	-0.458	-0.458
		(-4.27)**	(-4.28)**
Demand function for fertilizer			
Intercept	E0	2.904	2.904
		(20.02)**	(20.06)**
Cultivar	E2	1.250	1.250
		(6.10)**	(6.12)**

*** Significant at 1% level, * Significant at 5% level.*
Numbers in parentheses refer to t statistic.
Note: Factor demand functions refer to factor shares.

Table 4.4 **Estimated factor demand and output supply equations of barley**

Variable	Demand equations for				Barley supply
	Seed	Fertilizer	Machinery	Labor	equation
Intercept	0.286	0.126	0.086	-0.085	-1.101
Seed price	-1.416	-0.416	-0.416	-0.416	-0.416
Fertilizer price	-0.183	-1.183	-0.183	-0.183	-0.183
Machinery price	-0.125	-0.125	-1.125	-0.125	-0.125
Labor price	0.123	0.123	0.123	-0.877	0.123
Output price	1.601	1.601	1.601	1.601	0.601
Education	-0.086	-0.086	-0.086	-0.086	-0.086
Area	0.623	0.623	0.623	0.623	0.623
Cultivar	0.528	0.528	0.528	0.528	0.528

Table 4.5 **Impact of 'Rihan 03' on the demand for seed, fertilizers, machinery and labor**

	Impact of improved cultivar according to (%)		
	Input	Actual farm use	Estimated model
		OLS	SUR
Seed	6.2	15.6	23.0
Fertilizers	17.8	15.4	21.9
Machinery	14.8	20.0	29.0
Labor	14.1	18.6	28.5

Impacts were estimated at the sample average levels of the variables as follows:
Average price of seed = 78.0ID/kg; Average price of fertilizers = 42.7ID/kg
Average price of machinery = 156.9ID/kg; Average price of Labor = 94.8ID/kg
Average price of barley = 72.7ID/kg; Average price of education = 8.1/year
Average planted Area = 92.7ha

Table 4.6 **Estimated own price and cross price elasticities**

Dependent variable	Barley price	Seed price	Fertilizer price	Machinery price	Labor price	Land
	Estimated elasticities according to OLS					
Barley supply	0.782	-0.339	-0.228	-0.101	-0.114	0.884
Seed demand	1.782	-1.339	-0.228	-0.101	-0.114	0.884
Fertilizer demand	1.782	-0.339	-1.228	-0.101	-0.114	0.884
Machinery demand	1.782	-0.339	-0.228	-1.101	-0.114	0.884
Labor demand	1.782	-0.339	-0.228	-0.101	-1.114	0.884
	Estimated elasticities according to SURE					
Barley supply	0.601	-0.416	-0.183	-0.125	0.123	0.623
Seed demand	1.601	-1.416	-0.183	-0.125	0.123	0.623
Fertilizer demand	1.601	-0.416	-1.183	-0.125	0.123	0.623
Machinery demand	1.601	-0.416	-0.183	-1.125	0.123	0.623
Labor demand	1.601	-0.416	-0.183	-0.125	-0.877	0.623

These estimated price elasticities have important policy implications. They showed that output support price policy is more effective in increasing barley production than subsidizing input prices, such as seed and fertilizers. The combined effect of reducing the prices of both seed and fertilizers by 10% resulted in increasing barley production by 5.67%, which is less than the increase in barley price by 10% estimated at 7.82%. Similarly, the impact of output on input use was more effective than the combined or separated effect of subsidizing seed and fertilizer prices (Table 4.7). This requires giving output support price policies a priority in increasing barley production in Iraq. This result is consistent with the findings of previous studies in that output support price policy is more effective in increasing the growth of agricultural production in developing countries.

Table 4.7 **Policy implications of selected pricing policies for barley production**

Type of pricing policy	**Percentage of impact**				
	Seed use	**Fertilizer use**	**Machinery use**	**Labor use**	**Barley output**
1. Reducing seed price by 10%	13.90	3.39	3.39	3.39	3.39
2. Reducing fertilizers price by 10%	2.28	12.28	2.28	2.28	2.28
3. (1) + (2)	16.18	15.67	5.67	5.67	5.67
4. Increasing barley price by 10%	17.82	17.82	17.82	17.82	7.82

We conclude that two interrelated agricultural policies directly affect production. The first one is to introduce new technologies, such as improved cultivars in order to increase yield and then total production. The other policy is pricing policies of the output and inputs, which in return affect the use of variable input. The first type of these policies resulted in increasing total factor productivity by 19% compared to the productivity levels achieved under the local cultivar. This impact highly exceeds the effect of supporting output price or subsidizing input prices. Although support price policies increased output and thus input use, their effect was lower than the net technical impact of increased productivity of improved cultivar 'Rihan 03.' Thus, varietal barley production technologies contributed greatly to the increase of barley production in the rainfed area of Iraq under prevailing output support price and input subsidizing policies for fertilizers and other inputs. This calls for greater integration between pricing policies and activities of introducing improved technologies in order to facilitate technology adoption by farmers.

Concluding Remarks

Results of a farm level survey of 495 farmers show that average yield level of the improved barley cultivar 'Rihan 03' is 1.096ton/ha, compared to 0.772ton/ha for the local variety. This indicates a yield advantage of 42% associated with the use of 'Rihan 03.' The rainfall zone had a noticeable effect on barley yield. The yield of the improved cultivar was greater than that of the local by 67% in the MRA. The yield advantage was only 28% in the LRA. Overall, the improved cultivar had an important impact on total factor productivity. The use of the improved cultivar increased total factor productivity by 19%, compared to the local variety. This means that under the same levels of inputs use, the productivity of 'Rihan 03' was greater than that of the local cultivar by 19%. The type of this shift in barley production function is of neutral technical change. This means that the improved cultivar gives higher output per input unit compared to the local variety. This increase in productivity reflects the net impact of the cultivar's technical properties, which is lower than the combined impact of the cultivar and fertilizer.

Barley production under rainfed conditions was found to be of constant return to scale nature because the sum of output elasticities of land, seed, fertilizer, machinery, and labor was equal to unity. Thus, the new barley varietal technology appears to be neutral with respect to farm size, suggesting that large farms have no efficiency advantage over small farms. Results of this study show that large and small farms have equal economic and price efficiencies with respect to inputs of seed, fertilizer, machinery, and labor. This means that these farms have equal technical efficiency.

The estimate of factor demand and output supply functions demonstrated that the effect of any independent variable on the demand for seed, fertilizer, machinery and labor is symmetric. This is mainly attributed to the nature of Cobb-Douglas function, which assumes that elasticity of substitution between any pair of inputs is constant and equals to unity. However, the relationship between any pair of inputs is gross complements and not symmetric.

The improved cultivar has a great impact on the demand for variable production inputs. The use of 'Rihan 03' increased the demand for seed by 15.6–23%, fertilizer 15.4–21.9%, machinery 20–29% and labor 18.6–28.5%. These results have important policy implications in that the supplies of these inputs should be increased to their new demand levels in order to increase the efficiency of barley production under rainfed conditions.

Estimated price elasticities show elastic response to the demand for seed, fertilizer, machinery and labor with respect to changes in barley price. Similarly, all own price elasticities of the demand for variable inputs were elastic. Meanwhile, cross price elasticities were less (in absolute value) than the own price elasticities by one. The signs of all cross price elasticities were negative, suggesting a complementary relationship among variable production inputs. These price elasticities have important policy implications in that output support price policy is more effective in increasing barley production, compared to, for example, subsidizing input prices of seed and fertilizer. The combined effect of reducing the prices of both seed and fertilizer by 10% resulted in increasing barley production by 5.67%, which was less than the increase in barley output of 7.82% resulting from increasing barley price by 10%. Similarly, the impact of output price on input use was greater than that of changing factor prices.

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4.2 Economic Assessment of Barley-Forage Legume Rotations within the Framework of Risk Analysis

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Introduction

Several on-farm trials and demonstrations to introduce forage legumes into crop rotations with barley to replace fallow and/or continuous cropping have been conducted in Iraq since 1991. The decision regarding the type of rotation to be recommended for wide dissemination needs to be based on economic analysis, as there is a clear trade-off between expected income and yield variability associated with various rotations. In addition, rainfed farming is subject to inherent risk and, thus, any economic analysis that does not directly address the risk issue may lead to misleading decisions.

The present study aims at determining the stochastically efficient crop rotation within the framework of risk analysis in order to generalize its application in the low-rainfall areas of Iraq.

Materials and Methods

Five two-course crop rotations were tested in the low-rainfall area (200–350 mm) of Ninavah Province, North of Iraq: barley/common vetch (*Vicia sativa),* barley/medic *(Medicago* sp.), barley/common vetch/barley mixture, barley/barley and barley/fallow.

To better represent the targeted area for wide dissemination, on-farm researcher-managed trials were conducted in four locations, namely, Tel-Asmer, Musltan, l-Latra and Ain-Talawi. Grain and forage yields for these trials were obtained from annual reports of the Mashreq/Maghreb project. Monthly rainfall data were obtained from the meteorological agency for 1974–98. Enterprise budgets were developed for each crop based on input and output levels reported in the results of these trials and using input and output prices of 1996.

To estimate the production functions, cross-sectional data for the four locations was pooled with the time series for 1991/92–1997/98. This pooled time series cross-sectional data requires an appropriate estimation procedure to efficiently estimate the unknown parameters. The error-component method was used to estimate nine production functions using yield and rainfall information for the study period.

In order to use the estimated production functions to predict the yield levels for longer periods, and to better represent the possible rainfall pattern of the area, the estimated model was validated. Both in-sample and out-of-sample predictions were estimated for model validation. Three accuracy measures were used to judge the prediction performance of the estimated models. These are mean absolute error (MAE), root mean square error (RMSE), and mean absolute percentage error (MAPE).

After model validation, the estimated production functions were used to predict yield levels using the historical rainfall data for 1974–98. These predicted yield levels were used to calculate net returns for the five crop rotations.

To stochastically determine the efficient crop rotations, stochastic dominance analysis (SDA) was used. Two criteria of SDA were applied. The first degree stochastic dominance (FSD) assumes that a decision-maker prefers more to less of net return, implying that the first order derivative of the utility function is positive. The second ordering rule is the second degree stochastic dominance (SSD). In addition to the assumption that the producer prefers more to less of net return, the SSD requires an additional assumption; that the decision-maker is risk averse, suggesting that the second order derivative of the utility function is negative.

Results and Discussion

Rainfall information

Previous agronomic studies in the study area established that good plant growth requires about 50mm of rainfall for germination in autumn (October **+** November **+** December), and a total of 120–150mm of effective rainfall for the stage of plant filling in spring (March **+** April). Comparing these amounts of rainfall requirements with actual rainfall in 1974–1998 provides striking results. The percentage of years in which the average autumn rainfall was less than 50mm is 28%, with an average of 26.70mm, while the percentage of good years (>50mm) is 72%, with an average of 110mm. However, this does not necessarily mean that the distribution of the autumn rainfall was good. In such conditions, therefore, timing of planting is affected, which in turn affects yield.

For spring rainfall, 86% of the period had rainfall below the required amount, with an average of 59.4mm and only 140o of the years having good seasons, with an average of 147.43mm. This is an important result, as it clearly indicates how risky the study area is for agricultural production. Any economic analysis that ignores these risks will give unrealistic results.

For a season to be classified as a drought season the amount of spring rainfall (March **+** April **+** May) should be less than 60mm. Accordingly, 430o of the seasons were classified as drought in 1974–1998, with an average of 36mm.

Production functions and predicted yields

The production functions for each crop in each course of the rotation were estimated. These estimates provided important information on the months and/or season in which the rainfall was more effective in explaining the yield variability of barley, common vetch, medic and mixture. Table 4.8 summarizes these results. I-laying estimated the production functions, the second step was to use them to make in-sample yield predictions and compare them with actual yield levels (Table 4.9). Barley after common vetch had the highest grain yield of 1139.4kg/ha, followed by barley after mixture with 1112.69kg/ha (Table 4.9). The lowest barley grain yield (750.77kg/ha) was for continuous barley cropping. For the legume course of the rotation, common vetch/barley mixture had the highest dry matter yield of

1143.5kg/ha. The estimated production functions performed well in predicting in-sample yield levels. The prediction error did not exceed 2.50o at the worst case, suggesting that the estimated production functions were valid for out-of-sample predictions.

Table 4.8 **Effective rainfall months for barley/forage legume rotations**

Rotation	Effective rainfall months						
	March	April	Nov.	Mar.+Apr.	Oct.+Nov.	Nov.+Dec.	Oct.+Nov.+Dec.
Barley year							
Fallow/barley				X			X
Barley/barley	X	X			X		
Common vetch/barley			X	X			
Mixture/barley	X	X	X	X			
Medic/barley	X	X	X	X			
Legumes year							
Barley			X	X			
Common vetch	X				X		
Mixture				X		X	
Medic			X	X			

Yield levels were forecasted using historical weather data for 1974-1998 for each crop in the two-course rotation. The predicted yield levels were converted into net revenues for each course of the rotation. The net returns of the two courses were then summed up to obtain the net returns for the whole rotation. Their averages are presented in Table 4.10. It is clear that among forage crops, the barley/mixture rotation gave the highest net return, followed by the barley/common vetch rotation. However, the barley/common vetch rotation seemed to be more stable than the barley/mixture rotation, as the coefficient of variation (CV) of the former was lower than that of the latter.

Table 4.9 **Actual and predicted yield levels and prediction errors for barley/forage legumes rotations, 1993-1997**

Rotation	Yield (kg/ha)		Prediction error (%)
	Actual	Predicted	
Barley year			
Fallow/barley	928.00	927.909	0.00
Barley/barley	750.77	732.000	- 2.50
Common vetch/barley	1139.40	1135.00	-0.39
Mixture/barley	1112.69	1101.84	-0.97
Medic/barley	1057.82	1058.68	0.00
Legumes year			
Barley	755.93	755.809	0.00
Common vetch	763.21	745.202	- 2.36
Mixture	1143.50	1138.86	-0.41
Medic	762.37	745.504	- 2.20

Table 4.10 **Average net returns for barley/forage legumes rotations, 1974-98**

Rotation	**Net returns (Iraqi Dinars/ha)**		
	Mean value	**SD**	**CV (%)**
Barley/fallow	5779.34	10581.99	183.10
Barley/barley	8201.79	33397.44	407.20
Barley/common vetch	47975.68	47636.99	99.29
Barley/mixture	62793.66	72812.25	115.95
Barley/medic	34579.20	40586.21	117.37

Another important result was that the barley/barley rotation gave higher net return than the barley/fallow rotation. This is because under the barley/barley rotation you have grain yield for two consecutive years, whereas with the barley/fallow rotation you have grain yield for one year only. Furthermore, additional cost was associated with the fallow year, as the common farmers' practice in the study area is to have a clean fallow, which requires plowing costs. However, the barley/barley rotation is very volatile compared to the barley/fallow, as its CV exceeds that of the latter by almost threefold. It is difficult to choose among these alternative rotations unless the risk concept is directly taken into account. This is done by applying the SDA (Table 4.11).

According to the results in Table 4.11, the rotation of barley/common vetch, barley/mixture, and barley/fallow dominated the other alternatives with the second degree stochastic dominance. It is interesting that the barley/fallow rotation appears to be one of the efficient rotations, although its net return is not the highest. The main explanation for this is that its coefficient of variation is relatively low. More information on farmers' preferences and objectives is needed for selecting any rotation of the efficient set. For farmers on mixed crop/livestock enterprises, the rotation of barley/common vetch and barley mixture are recommended, as they better serve the goal of crop/livestock integration. Type of land tenure is an important factor in the selection of the rotation type. For sharecropping type of land ownership, the barley/fallow rotation may appear a sound recommendation.

Table 4.11 **Results of the first degree stochastic dominance (FSD) and the second ordering rule is the second degree stochastic dominance (SSD) for barley/forage legumes rotations**

Rotation	Location				
	Tel-Asmer	Musltan	Hatra	Ain-Talawi	Whole sample
Barley course					
Barley/fallow	0	0	0	FSD	0
Barley/barley	0	0	0	0	0
Barley/common vetch	SSD	SSD	SSD	SSD	SSD
Barley/mixture	SSD	SSD	SSD	SSD	SSD
Barley/medic	SSD	SSD	SSD	SSD	SSD
Legumes course					
Barley	SSD	SSD	SSD	SSD	SSD
Common vetch	SSD	SSD	SSD	SSD	SSD
Mixture	SSD	SSD	FSD	SSD	SSD
Medic	FSD	0	0	0	0
Whole rotation					
Barley/fallow	0	SSD	SSD	SSD	SSD
Barley/barley	0	0	0	0	0
Barley/common vetch	SSD	SSD	SSD	SSD	SSD
Barley/mixture	SSD	SSD	FSD	SSD	SSD
Barley/medic	0	FSD	0	SSD	0

4.3 Monitoring the Adoption of Feed Block Technologies

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Objectives

- To monitor the adoption rate of the feed block technology and forage legumes by sheep owners and manufacturers and identify with them any emerging new constraints.
- To determine the main factors affecting adoption rate, degree and intensity of adoption of the technology.

Materials and Methods

Farm level data were collected using a questionnaire to estimate the impact of the feed block technology. Field visits were made to manufacturing plants to monitor the manufacture of the feed blocks and the demand for the technology. Production system, flock size, education level of sheep owners, availability of extension services, profitability of technology and risk associated were the main factors studied.

Results

Monitoring feed block technology
The feed block technology is usually subject to continuous economic evaluation in order to monitor its adoption among sheep owners. Information on 81 sheep owners was collected, including flock size, amount of feed blocks bought, and number of times a sheep owner bought the feed blocks during the season. Information collected revealed the following:

1. Sheep owners of all flock sizes use feed blocks to supplement the feeding of their sheep. Most of the sample farmers (42%) had small flock size of 50–150 heads, with an average of 113 heads. Medium flock size sheep owners represented 21% of sample farmers, ranging from 151 to 250 heads, with an average of 219 heads. An additional 16% of them had average flock size of 315 heads, ranging from 251 to 350 heads. The fourth group (21% of the farmers) was the sheep owners of large flock size of 622 heads, ranging from 400 to 1500 heads.
   Thus, sheep owners were categorized into three. The first category was 50–150 heads, accounting for 42% of the sample, while the second was medium size of 151–350 heads, representing 37% of sheep owners. The third category had more than 350 heads and accounted for 21% of the sample.

The distribution of sheep population among these categories was another important aspect of the monitoring process. Although the first group accounted for 42% of the sheep owners, they controlled only 17% of the sheep population. While the second group represented 37% and controlled 35% of the sheep population. The third group, however, had 48% of the sheep population with only 21% of sheep owners.

These results have important policy implications in that a large sheep population is concentrated in a small portion of sheep owners. Thus, feed block technology will have a larger impact if it is widely adopted by large flock sheep owners, given the concentration of sheep population among farmers in this group.

However, equity issues may call for more attention to small flock farmers since they represent a larger percentage of adopters. Furthermore, small farms usually have limited financial resources, and, thus, are not able to buy costly feed. Making feed blocks available will enable them to manage their flocks during drought seasons. For the Mahalabia community, the average flock size was 165 heads, whereas average flock size in Ain-Talawi community was 513 heads.

Table 4.1 **Distribution of sheep owners and flock sizes**

Flock category (head)	Average flock size (head)	Sheep population		Sheep owners	
		No.	%	No.	%
50-150	113	3842	17.3	34	42
151-250	219	3723	16.7	17	21
251-350	315	4095	18.4	13	16
> 350	622	10574	47.6	17	21
Total	410*	22234	100	81	100

**Weighted average of flock size for the whole sample, with sheep population used for weighting.*

2. To assess the use of feed blocks on a sustainable basis, the frequency of buying feed blocks by sheep owners during the 1999/2000 season was recorded. Results show that 53% of sheep owners bought feed blocks once in the season, while 31% bought feed blocks twice. More interesting is that some 16% of sheep owners bought feed blocks three times or more, up to seven times. On average, sheep owners bought feed blocks twice during the season, implying that they used the technology on a sustainable basis.

Table 4.13 **Frequency of using feed blocks by sheep owners**

Frequency of using the technology	Number of farmers	
	No.	%
Once	43	53
Twice	25	31
Thrice	13	16
Total	81	100

1. Feed blocks contributed greatly to feed resources in the 1999/2000 season. The sample farmers bought 223 tons of feed blocks during the season, with an average of 11.4kg of feed blocks per head. Some sheep owners used a maximum of 85kg per head. Given the fact that it was a drought season, there were few alternative highly nutritive feed sources. Thus, the feed blocks bridged the feed gap for many sheep owners.

2. Flock size is an important factor affecting the number of feed blocks used. A regression equation was estimated relating the amount of feed blocks bought (as a dependent variable) to the flock size (as an independent variable). The estimated equation shows that there is a positive relationship between the number of feed blocks used and flock size. The estimated slope coefficient indicates that increasing the flock size by one sheep would increase the use of feed blocks by 7.2kg per head. The slope coefficient was significant at 0.01 level. However, the estimated coefficient of multiple determination (2R) indicated that flock size explains about 18% of the variation in the use of feed blocks by sheep owners. Other variables that were not included in the regression equation explain the remaining variation. The F–test shows that the estimated regression equation was significant at the 0.01 level, supporting the reliability of the estimated relationship. The estimated regression equation is:

    Feed blocks = 785.01 + 7.23** flock size

    t = (1.26) (4.20)
    R^{-2} = 0.18
    F = 17.62**

*Note: Numbers in parenthesis refer to t–test. ** Significant at 0.01 level*

Total feed blocks produced by the private sector plants and IPA manufacturing units was estimated at 35,858 tons, distributed among 8458 sheep owners. The progressive increase in feed blocks and beneficiaries is depicted in Figure 4.1, which clearly demonstrates an expansion in the production of this technology and its wide adoption.

Economic feasibility of using feed blocks in sheep feeding

Previous on-farm demonstrations and on-station trials have shown the importance of feed blocks in improving the efficiency of sheep production. The use of feed blocks results in increasing sheep production efficiency by 32% because of increasing reproductive efficiency and, thus, increasing the number of lambs born. Results show that the use of feed blocks led to an increase in meat and milk production of 4.09 and 8.28kg/ewe/year respectively. This increase in meat and milk production required a total intake of 116kg/ewe/year of feed blocks in addition to the use of conventional feed resources (barley grain, straw and green fodder).

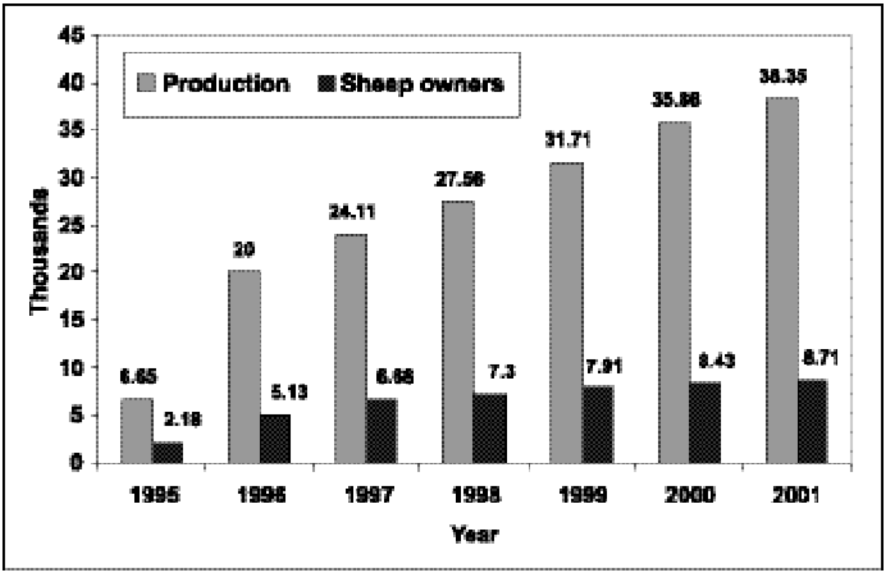

Figure 4.1 **The development of feed blocks technology in Iraq**

Benefit-cost analysis was used to assess the economic feasibility of using feed blocks in sheep feeding. Based on this analysis the benefits associated with additional meat and milk production can be compared with the costs of feed blocks used in animal diet.

Benefit-cost ratio (B/C) and IRR were used for this assessment. The calculation of B/C ratio and IRR was based on:

- Increase in meat and milk production of 4.09 and 8.28kg/ewe/year respectively.
- A period of eight years based on annual amounts of feed blocks used in sheep feeding in 1994–2001.
- Marginal cost of 4060ID/ewe/year associated with the use of feed blocks.
- A discount rate of 10%, which is equal to the interest rate paid by banks.

The B/C ratio was calculated using the following formula:

$$B/C = \Sigma\ (B_t/(1+r)^t)/\Sigma(C_t/(1+r)^t)$$

Where: B_t = annual benefits
C_t = annual costs
r = discount rate

IRR is the discount rate for which B – C = 0.

Based on this, the calculated B/C ratio was 1.56 and the IRR 87%. These results indicate that high economic returns are associated with the use of feed blocks in sheep feeding. The B/C ratio implies that an additional return of 0.56 ID is associated with each ID invested in feed blocks. Comparing the IRR of 87% with the effective rate of interest of 10% indicates that investment in feed blocks for sheep feeding pays high dividends.

Table 4.14 **Benefits and costs of using feed blocks in sheep feeding**

Year	Annual feed blocks production (tons)	Annual benefits ('000 ID)	Annual costs ('000 ID)
1994	6650	0	232752
1995	6650	446643.2	232752
1996	13350	896643	467253.2
1997	4100	273373.4	143501
1998	3450	231731	120748.5
1999	4150	278731	1451251
2000	4150	278731	1451251
2001	2500	167912.2	87501

1kg meat = 1500ID; 1kg milk = 200ID

5

Adoption and Impact of Improved Technologies in Jordan

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General Background

The total land area of Jordan is about 9 million hectares, of which only 5% is cultivated land (0.5 million ha), mostly under rainfed conditions. Cultivated land is used to produce field crops and fruit trees. The marginal area in Jordan includes 70% of the arable land, where about 41% of the population live. Farming systems in the area are characterized by low productivity of barley, forage and red meat. Farmers use traditional methods in preparing land, and most of them do not apply fertilizers, which results in low productivity of crops.

This study is based on data collected from 155 farmers in the 2000/2001 season using a questionnaire. The data was collected randomly from different sites of Jordan: north (70), middle (45) and south (40), as shown in Table 5.1. Farmers were classified into three groups, which were, participants in demonstrations, participants in field days, and non-participants. Descriptive statistics was used to analyze the data including means, percentages, and frequencies.

The questionnaire sought for general information about the farmers; technologies adopted for both animal and plant production through the project; purposes, objectives and constraints related to the adoption of the technologies; and positive and negative effects of implementation. Data on farm budget were also collected. Adoption rates for improved barley varieties, feed blocks, early weaning and planting bekia were calculated, and impact assessments conducted for early weaning and feed blocks.

Data on the adoption rate and degree of adoption were analyzed in five categories, namely, land tenure, flock size, farm size, type of participation, and type of production system. Economic evaluation and productivity comparisons were calculated for early weaning and feed blocks. The degree of adoption represents the area planted with the improved variety in comparison to the total farm size.

Farm size in the sample ranged from 46 to 668 dunums. The average farm size was 45.96, 151.46 and 667.86 dunums for small, medium and large farms respectively (Table 5.2). Average flock sizes for small, medium and large farms were 35, 126 and 478 heads respectively.

Table 5.1 **Distribution of sample farms by location within Jordan**

Site	Sample size	
	No. of farmers	% of farmers
North Jordan	70	45.2
Middle Jordan	45	29.0
South Jordan	40	25.8
Total	155	100

Table 5.2 **Distribution of sample farms by size**

Farm size	Average farm size (dunum)	% of farms	% of area
Small	45.96	37.5	10.8
Medium	151.46	53.3	50.6
Large	667.86	9.2	38.6
Total	159.46	100	100

Small farm £ 100 dunum; medium farm = 101-500 dunums; large farm > 500 dunums

Table 5.3 **Distribution of sample farms by flock size**

Flock size	Average flock size (head)	% of farms	% of sheep
Small	35	36.4	8.9
Medium	126	49.1	42.9
Large	478	14.5	48.2
Total	144	100	100

Small flock £ 50 head; medium flock = 51-250 head; large flock > 250 head

Background on the Use of the Technologies

Usually farmers supplement feed for their flocks with barley, barley and wheat bran, wheat bran, straw and barley, but very few farmers add minerals, salts and vitamins or try to offer complete rations. Though some farmers used olive by-products in the feedstuff, use of agricultural by-products (feed blocks) was not common. The feed blocks project first started as a research at Al-Khanasreh sheep research station of NCARTT. Different formulae for making feed blocks were tested under station conditions and subsequent demonstrations (on-farm trails) conducted at different locations for different purposes, including fattening, fertility, and growth.

An adoption survey in 1996 showed that 38.8% of the farmers had heard about feed blocks, while 33.8% were interested and willing to buy feed blocks from the market. Three manufacturing units producing 40 tons of feed blocks were imported from Iraq in 1998 for large-scale production and were established at Ramtha, Meshqar, and Rabbeh. Based on the imported model, NCARTT made two additional units in 1999 that produced additional 118 tons of feed blocks. Due to drought and increase in demand for feed blocks, three more units were established, making the total of feed blocks units eight.

A survey conducted in 1999 showed 20.8% adoption rate of feed blocks, and 84% of the farmers were keen to feed their animals continuously on the feed blocks.

Early weaning

Sheep owners traditionally leave lambs for prolonged suckling, sometimes exceeding three months. Results of demonstrations of early weaning conducted in Jordan showed a considerable increase in milk production, early supply of milk when price may be high, resulting in sustainable profitability. The Mashreq/Maghreb Project introduced this technology to farmers through on-farm trials, which were later scaled up to the community level. Economic studies showed that extra income to farmers in Jordan resulting from early weaning ranged from 2.3 to 4.3JD/ewe/season in 1992–1995. The adoption rate of the technology was estimated to be about 28.8% among all farmers.

Improved barley varieties

Farmers in Jordan mainly plant two local varieties of barley, 'Al-Arqadi' and 'Arabi', with about 50kg/dunum yield. The improved variety 'Al-Arqadi' was introduced to farmers in 1975 by cooperatives, Ministry of Agriculture, and the private sector. About 90% of farmers plant 'Al-Arqadi' because of its high yield, while 10% plant 'Arabi' because of its tolerance to drought.

The Mashreq/Maghreb Project proposed to solve the problem of low productivity of barley based on results of research conducted by the national program and cooperative research projects with some international centers. The results enabled the project team to define the most suitable farming practices for barley production. The improved practices and technologies led to a significant increase in barley grain and straw. Usually, the yield of barley did not exceed 63kg dunum, but studies showed that by using the full package technologies and planting improved barley varieties, productivity increased by about 25–30%, with yields of the improved varieties reaching 90–100kg/dunum. The adoption rate of the improved barley varieties was about 55.3%.

Planting bekia

The rainfed farming system in Jordan is based on a delicate balance between field crops, livestock, trees, rangeland, and grazing fallow land. The cereal/fallow system is the main feature of field crop production in the rainfed areas. One-third of the cultivated land used to be left as fallow. Therefore, forage legumes such as vetch were introduced into the farming system through the M&M Project to replace fallow land. Vetch is a valuable crop that provides fodder for livestock, improves soil fertility and texture, and increases farmers' income.

Farmers in Jordan prefer bekia to other forage legumes because of its high productivity and palatability for animals. Moreover, local vetch proved to be well adapted to the environmental conditions in Jordan. Thus, the project demonstrated the benefits of replacing the fallow year with bekia in the fallow/barley rotation or replacing one-year barley in the continuous barley system.

The dry matter yield for vetch was 350–600kg/ha, and adoption rate for farmers who planted bekia was about 28.5%.

Adoption Rate and Degree of Adoption

Feed block technology

Table 5.4 shows the adoption rate of feed blocks according to type of participation. The highest rate of adoption for farmers who participated in demonstrations was 80%, while it was 41.9% for farmers who participated in field days. Average adoption rate of feed blocks regardless of type of participation was 20.8%.

Table 5.4 **Adoption rate of feed blocks by type of participation**

Type of participation	% of farmers	Adoption rate (%)
Demonstrations	8.0	80.0
Field days	24.8	41.9
Non-participants 67.2	6.0	
Total	100	20.8

Early weaning

Table 5.5 shows that the adoption rate of early weaning technology was 100% for farmers who participated in demonstrations, while it was 52.8% for farmers who participated in field days. Average adoption rate was 28.8% regardless of type of participation.

Table 5.5 **Adoption rates of early weaning technology by type of participation**

Type of participation	% of farmers	Adoption rate (%)
Demonstrations	9.6	100
Field days	28.8	52.8
Non participants	61.6	6.5
Total	100	28.8

Improved barley varieties

The adoption rate of improved barley varieties for farmers who participated in demonstrations was 92.3%, while it was 48.1% for farmers who participated in field days. Average adoption rate was 55.3 % and the average degree of adoption was 63.2% (Table 5.6).

Table 5.6 **Adoption rate and degree of adoption for improved barley varieties by type of participation**

Type of participation	% of farmers	Adoption rate (%)	Degree of adoption (%)
Demonstrations	33.3	92.3	90.1
Field days	34.6	48.1	55.5
Non participants	32.1	34.0	35.9
Total	100	58.3	66.6

Table 5.7 shows the adoption rate of improved barley varieties according to land tenure system. The highest rate of adoption was by farmers who owned their land (55.1%), while adoption rate was 52.5% for those who rented the land.

Table 5.7 **Adoption rate of improved barley varieties by type of land tenure system**

Land tenure system	Adoption rate (%)
Owned	55.1
Rented	52.5
Shared	25.0
Meeri (common/public)	*25.0*
Total	53.3

Planting bekia

Table 5.8 shows the adoption rates for planting bekia. Similar to other technologies, the highest adoption rate was by farmers who participated in the demonstrations (47.6%), followed by those who participated in field days (40%). Average adoption rate was 28.5%. These results show that demonstrations and field days are effective ways to introduce new technologies to farmers.

Table 5.8 **Adoption rate of bekia according to type of participation**

Type of participation	% of farmers	Adoption rate (%)
Demonstrations	30.7	47.6
Field days	18.2	40.0
Non participants	51.1	12.9
Total	100	28.5

Table 5.9 shows the adoption rates of planting bekia in relation to land tenure system. The highest percentage of adoption was by farmers under the *meeri* land (50%), followed by farmers who shared land (42%), while the lowest was by farmers who owned land (24.6%). This may be because farmers prefer to plant their own land with barley and wheat, and would rather plant bekia on *meeri* and shared land.

Table 5.9 **Adoption rate of bekia by type of land tenure system**

Land tenure system	Adoption rate (%)
Owned	24.60
Rented	27.50
Shared	42.00
Meeri	50.00
Total	29.74

Table 5.10 shows the adoption rate and the degree of adoption of improved barley varieties according to farm size. The highest rate of adoption (32.2%) was by farmers with medium size farms (152.1 dunums) and the degree of adoption was 30.7%. This indicates that farmers with medium holdings are more interested in new technologies than other farmers. The lowest rates of adoption observed in small holdings could be because small farms are scattered and not suitable for machinery. Low adoption of improved barley varieties in large farms is because these farms are mainly located in low rainfall areas that are not suitable for planting the improved varieties.

Table 5.10 **Adoption rate and degree of adoption of improved barley variety by farm size**

Farm size	Average farm size	Adoption rate (%) (dunum)	Degree of adoption (%)
Small	46.84	16.4	4.8
Medium	152.10	32.2	30.7
Large	670.00	6.6	27.6
Total	182.43	55.3	63.2

Table 5.11 shows the adoption rate and degree of adoption of planting bekia according to farm size. The highest adoption rate and degree of adoption were 67.6% and 64.2%, respectively, for farmers with medium farms.

Table 5.11 **Adoption rate and degree of adoption of bekia by farm size**

Farm size	Average farm size (dunum)	Adoption rate (%)	Degree of adoption (%)
Small	15.29	18.9	8.5
Medium	32.16	67.6	64.2
Large	68.40	13.5	27.3
Total	33.86	100	100

Table 5.12 shows the adoption rate and degree of adoption of feed block technology according to flock size. The highest adoption rate and degree of adoption were by farmers who owned medium flocks (72.7% and 61.8% respectively).

Table 5.12 **Adoption rate and degree of adoption of feed blocks by flock size**

Flock size	Average flock size (head)	Adoption rate (%)	Degree of adoption (%)
Small	27	13.6	2.6
Medium	120	72.7	61.8
Large	367	13.6	35.6
Total	141	100	100

Table 5.13 shows the adoption rate and degree of adoption of early weaning technology according to flock size. The highest adoption rate was by farmers who owned medium flocks (60.6%) and the highest degree of adoption (49.5%) was for large flocks.

Table 5.13 **Adoption rate and degree of adoption of early weaning by flock size**

Flock size	Average flock size (head)	Adoption rate (%)	Degree of adoption (%)
Small	34	18.2	3.2
Medium	150	60.6	47.3
Large	448	21.2	49.5
Total	192	100	100

Table 5.14 shows the adoption rate and degree of adoption of improved barley varieties according to flock size. The highest adoption rate was by farmers who owned medium flocks (27.8 %) and the highest degree of adoption (21.2%) was for large flocks.

Table 5.14 **Adoption rate and degree of adoption of improved barley varieties by flock size**

Flock size	Average flock size (head)	Adoption rate (%)	Degree of adoption (%)
Small	34	13.9	3.3
Medium	120	27.8	23.0
Large	472	6.5	21.2
Total	142	48.1	47.5

Table 5.15 shows the adoption rate and degree of adoption of farmers planting bekia according to flock size. The highest adoption rate was by farmers who owned medium flocks (55.6 %) and the highest degree of adoption (54.9 %) was for large flocks.

Table 5.15 **Adoption rate and the degree of adoption of Bekia according to flock size**

Flock size	Average flock size (head)	Adoption rate (%)	Degree of adoption (%)
Small	40	25.9	6.1
Medium	120	55.6	39.0
Large	505	18.5	54.9
Total	170	100	100

Table 5.16 shows the adoption rate of improved technologies according to type of production system. The data shows that the rate of adoption of improved barley varieties increased under the integrated system. This means that emphasis should be placed on integration of production systems especially if the straw of the barley varieties is palatable for sheep feeding.

Table 5.16 **Adoption rate (%) of improved technologies by type of production system**

Production system	Bekia	Early weaning	Improved barley varieties	Feed blocks
Crop production	25.6	0	31	0
Integrated (crop and livestock)	23.2	33	54	22

Constraints to Adoption of New Technologies among Sample Farmers

Mortality, especially in goats, was the major constraint reported by most farmers for not adopting the feed block technology. Other constraints were digestive system disorders and abortion. The main constraint for early weaning was the costs involved, while for improved barley varieties it was the shortage of harvesting machines and drought. The constraints farmers faced with growing bekia were inadequate rainfall and high cost of manual harvesting.

Impact assessment

Baseline information
Data for this study were collected mainly from northern Jordan (average annual rainfall < 250mm) where the first phase of the M&M Project was implemented. In addition, about 70 copies of the questionnaire were collected from the study communities and neighboring communities in northern Jordan during phase two of the project.

Rapid rural appraisal surveys (RRA) were conducted in communities participating in the M&M project to generate baseline information about the agro-ecological zones of the selected villages by tenure regime, key natural resources, and characteristics of the production systems such as livestock production, rangeland management, gender and socioeconomics.

Sustainability of technology
Several plant and animal technologies were transferred to the farmers. These were included feed block technology, early weaning, planting bekia in crop rotation, and full package of barley. However, the new technologies and practices cannot be efficient unless they are applicable in the present farm conditions, profitable to farmers, economically feasible at the national level and environmentally sound.

Sustainability of feed block
About 95.5% of farmers that used the feed blocks expressed interest in continuing to use it (Table 5.17). As indicated in Table 5.18, 63.6% of them used feed blocks three times, which is an indicator of technology sustainability. The demand for feed blocks increased during the drought season; one NGO started producing it commercially, while extension agents made the technology part of their plan.

Table 5.17 **Would you like to continue using feed blocks?**

	Frequency	Percentage
Yes	21	95.5
No	1	4.5
Total	22	100

Table 5.18 **Number of times farmers used feed blocks**

No. of times	Frequency	Percentage
2	3	13.6
3	14	63.6
Total	17	77.3
Missing system	5	22.7
Total	22	100

Mean number of times of using feed block technology = 3

Sustainability of early weaning

For early weaning technology, about 78.8% (Table 5.19) of the farmers who adopted this technology wanted to continue using it. About 42.5% of them used the technology three times (Table 5.20). This is an indicator of its sustainability. The extension agents considered this technology part of their extension program.

Table 5.19 **Would you like to continue using early weaning?**

	Frequency	Percentage
Yes	26	78.8
Missing	7	21.2
Total	33	100

Table 5.20 **Number of times farmers used early weaning technology**

No. of times	Frequency	Percentage
1	4	12.1
2	7	21.2
3	18	42.5
Total	29	78.9
Missing system	4	12.1
Total	33	100

Mean number of times of using early weaning technology = 3

Sustainability of improved barley varieties

Majority of farmers who adopted the improved barley varieties (91.7%) indicated interest in continuing to grow them (Table 5.21).

Table 5.21 **Would you like to continue planting improved barley varieties?**

	Frequency	Percentage
Yes	77	91.7
No	4	4.8
Total	81	96.4
Missing	3	3.6
Total	84	100

Planting bekia

The percentage of farmers, among adopters, who wanted to continue planting bekia was 48.6% (Table 5.22) and about 29.7% of them used it three times (Table 5.23).

Table 5.22 **Would you like to continue planting bekia?**

	Frequency	Percentage
Yes	18	48.6
No	4	10.8
Total	22	59.5
Missing	15	40.5
Total	37	100

Table 5.23 **Number of times farmers planted bekia**

No. of times	Frequency	Percent
1	10	27.0
2	1	2.7
3	11	29.7
Total	22	59.5
Missing system	15	40.5
Total	37	100

Mean number of times farmers planted bekia = 3

Impact on productivity

Results of the study on early weaning of lambs showed a considerable increase in milk production. Early production of milk as a result of adopting the technology when seasonal price was high resulted in substantial increase in farm profitability. In general, early weaning did not affect total weight gain in lambs. An average of 0.0386JD/lamb additional feed cost was associated with the practice (Table 5.24), while the average additional revenue was 7JD/lamb. The net additional revenue to the farmer resulting from early weaning was, therefore, 6.96JD/lamb.

Table 5.24 **Production and revenue from milk using early weaning**

Item	With early weaning	Without early weaning	Whole sample
Production (kg/head/day/before weaning)	0	0.4562	0.4651
Production (kg/head/day/after weaning)	0.4989	0	0.4651
Revenue from milk (JD)	24.1629	17.1221	18.5889
Cost added	0.0386		.03849

Additional revenue as a result of early weaning = 7JD/head, with 29% increase.

Results show that additional revenue for the feed block technology was 3.56JD/head, while the additional net return for using the technology was 5.35JD/head, with a 15.5% increase over farmers not using it (Table 5.25). It is also important to note that data for this study was collected during a drought season.

Table 5.25 **Adoption rate (%), additional revenue (JD/head), additional cost (JD/head), and additional net return (JD/head) for adopting feed blocks and early weaning technologies**

Technology	Adoption rate (%)	Additional revenue (JD/head)	Additional cost (JD/head)	Additional net return (JD/head)
Feed blocks	20.8	3.56	(1.79)*	5.35
Early weaning	28.8	7	0.0386	6.9614

**Value between brackets is negative.*

Table 5.26 **Feed cost and return from sheep production in Jordan (JD/head)**

Item	With F.B	Without F.B	Whole sample
Total return	59.27	55.71	56.4
Total cost	24.76	26.55	26.2
Net return	34.51	29.16	30.2

Net return from using feed blocks increased by 15.5% during drought season, equivalent to 5.35JD/head.

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6

Impact of Improved Barley Varieties in Lebanon

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Sampling Approach

Aarsal and Deir el Ahmar communities in Baalbeck Province were selected for the study because they represent the different farming and property rights systems in the low rainfall areas. The population of each selected community was stratified according to the three farming systems (livestock, crops and crop/livestock).

Aarsal

This is the largest community in Baalbeck Province, located 38km northeast of Baalbeck city at an altitude of 1400m above sea level, with semi-arid climate and annual rainfall of 150–350mm. It has a total population of 25,000 people and about 4000 families. An estimated 25% of the population are immigrants. The total area of Aarsal is 22,000ha, of which 13,200ha is arable and 5500ha rangeland. There are three types of land tenure, namely, private, miry and wadeh yad.

Traditionally, agriculture — rainfed cereals and legumes and small ruminant production — is the main source of livelihood for most families in Aarsal. Barley is the most important cereal crop, with at least 200ha cultivated annually.

Degree and Rate of Adoption in Aarsal

Sample farmers comprised those who hosted barley demonstrations (50%), field day attendees (32%), and non-participants in the project activities (18%). The highest adoption rate (39.5%) was found among farmers who hosted the project demonstration. They allocated nearly one-third (32.5%) of their land for growing improved barley variety (Table 6.2). Nearly 24% of field day attendees adopted the improved variety, and they allocated 44% of their land for the new varietal technology. The lowest adoption rate of 11% was observed among non-participant farmers, who allocated 18% of their land for the improved barley variety. The overall adoption rate was 30% of total sample farms, and the degree of adoption was 34% of total barley fields in the study area.

Table 6.1 **Distribution of farmers' by type of participation**

Type	Improved barley		Local barley		Total	
	Number	%	Number	%	Number	%
Demonstrations	15	53.6	4	40	19	50.00
Field days	9	32.1	3	30	12	31.58
Non-participants 4	14.3	3	30	7	18.42	
Total	28	100	10	100	38	100

Table 6.2 **Rate and degree of adoption of improved barley by type of participation**

Type	Number	%	Rate of adoption	Degree of adoption
Demonstrations	15	53.6	39.47	32.54
Field days	9	32.1	23.68	43.93
Non-participants	4	14.3	10.52	18.14

The adoption indicators varied with respect to farm size (Table 6.3). Nearly 24% of small farms (≤ 10 dunums) adopted the improved variety but allocated only 6% of barley lands for it. The percentage of area planted with the improved variety increased as the farm size. Large farms (>30 dunums) allocated nearly 48% of barley area to the improved variety. Similarly, medium farms (20-30 dunums) allocated 21% of their land to improved barley variety.

Table 6.3 **Rate and degree of adoption of improved barley by farm size**

Farm size (dunum)	Number	%	Rate of adoption (%)	Degree of adoption (%)
0-10	5	17.9	23.8	6.12
10-20	16	57.1	24.18	11.68
20-30	6	21.4	8.05	21.17
≤ 30	1	3.6	6.14	48.31

Type of income source is another important factor explaining variation in the adoption of improved varieties. The improved barley variety was adopted by 18% and planted in 10% of the land area of farmers who depended on crop production as their main income source. The rate and degree of adoption were higher among farmers practicing mixed crop/livestock enterprises (Table 6.4). The adoption rate for this group was 20% and the degree of adoption was 15%.

Table 6.4 **Rate and degree of adoption of improved barley by source of income**

Source of income	Number	%	Rate of adoption	Degree of adoption
Crop production	4	12.9	18.12	10.25
Mixed (crop/livestock)	24	7.1	20.33	14.62

The type of land tenure did not appear as an important factor in explaining variations in adoption indicators. This is because private ownership is the predominant type of land tenure in Aarsal community. The adoption degree was 14% for both private and miry (Table 6.5) and mixed (private + rented) land tenure systems.

Table 6.5 **Rate and degree of adoption of improved barley by type of land tenure**

Type of tenure	Number	%	Rate of adoption	Degree of adoption
Private or miry	21	71.8	19.14	14.28
Private + rented	7	28.2	22.57	13.14

Deir el Ahmar

Deir el Ahmar is located 6km west of Baalbeck City and has a total land area of 4146ha at altitude 1000m. The climate is semi-arid, with average annual rainfall of about 250mm. The total number of households is 16,000. About 60% of the agricultural land is irrigated while the remaining 40% is rainfed. The major crops are cereals, mainly barley and wheat, vegetables, legumes and fruit trees. Livestock kept is mainly goats, sheep and few heads of cattle.

Degree and Rate of Adoption in Deir El Ahmar

Data in Table 6.6 indicate that sample farms comprised those who that hosted the project demonstrations (36%), field day attendees (55%), and non-participants (9%). Farms in all the groups grew both improved and local barley varieties. Adoption indicators among participants support the effectiveness of the community approach adopted by the project in disseminating the technology among farmers. Nearly 32% of farmers hosting the demonstrations adopted the technology and allocated 46% of their land for improved barley variety (Table 6.7). Likewise, about 36% of field day attendees adopted the improved variety and planted it in 20% of their barley area. Adoption rate was lowest (4.5%) among non-participants. However, this group allocated 24% of their barley area to the improved variety.

In terms of farm size, the degree of adoption increased with increase in farm size (Table 6.8). Rate and degree of adoption for small farms (? 10 dunum) were 18% and 6% respectively. However, nearly 9–11% of the medium farms (10–30 dunum) adopted the improved variety and planted it in 12–24% of their land.

However, large farms (> 30 dunum) allocated most of their barley area (68%) to the improved variety.

Type of enterprise did not appear as an important factor in adoption indicators. About 31% and 33% of land was devoted to the improved variety by crop producers and mixed crop/livestock systems respectively (Table 6.9). The rate of adoption, however, varied by type of enterprise, with crop producers observing the highest adoption rate.

Land tenure is a critical factor for the adoption of improved barley technology in Deir El Ahmer community. Data in Table 6.10 show that farmers of privately owned land devoted nearly 61% of their land to the improved variety. Whereas, those of private + mixed land tenure allocated only 22% of their barley area to the improved variety.

Table 6.6 **Distribution of farms by type of enterprise**

Types	Improved barley		Local barley		Total	
	Number	%	Number	%	Number	%
Demonstrations	7	43.8	1	16.67	8	36.4
Field days	8	50.0	4	66.66	12	54.5
Non participants	1	6.2	1	16.67	2	9.1
Total	16	100	6	100	22	100

Table 6.7 **Rate and degree of adoption of improved barley by type of enterprise**

Types	Number	%	Rate of adoption	Degree of adoption
Demonstrations	7	43.8	31.9	46.14
Field days	8	50.0	36.4	20.37
Non participants	1	6.2	4.5	24.31

Table 6.8 **Rate and degree of adoption of improved barley by farm size**

Farm size (dunum)	Number	%	Rate of adoption	Degree of adoption
0-10	2	12.5	17.51	6.13
10-20	5	31.3	8.61	12.20
20-30	4	25.0	10.75	24.25
≤ 30	5	31.3	12.22	68.11

Table 6.9 **Rate and degree of adoption of improved barley by source of income**

Source of income	Number	%	Rate of adoption	Degree of adoption
Crop production	8	50	12.87	31.12
Mixed (crop/livestock)	8	50	9.87	32.75

Table 6.10 **Rate and degree of adoption of improved barley by type of land tenure**

Type of tenure	Number	%	Rate of adoption	Degree of adoption
Private or miry	4	25	14.13	60.50
Private + rented	12	75	10.50	22.33

Impact Assessment

The farm was the basic unit for impact assessment because the project worked with farmers on the introduction of new, improved technologies on their farms. A questionnaire was used to collect the required data from farmers. Data were collected on area planted with improved varieties; quantity and cost of seed, fertilizer and insecticide; labor costs and number of workers; cost of machinery and numbers of machine working hours; quantities produced and consumed; market prices of the produce; and other important factors. An *ex-post* analysis was also conducted on actual adoption rate, actual yield gain/cost reduction, prices and quantities for the whole period.

Methodology used for impact assessment included comparisons of the technologies (local versus improved variety), especially on yield productivity (grain/straw), cost and returns, Gini coefficient, and the production function (net impact).

Crop productivity

Data collected during Phases I and II of the project on several demonstration trials showed that the improved varieties were superior in grain and straw yield under the drier conditions of the project areas.

Cost and returns

An analysis of inputs and outputs was conducted. The inputs reflected the total cost of different factors of production including quantity of seed/dunum * prices of seed/kg, and number of hours of machinery/dunum * prices/hour. The outputs included quantity of seed produced/dunum * prices of barley/kg; quantity of straw produced/dunum * prices of straw/kg. The net revenue was calculated as the total revenue minus the total cost.

Calculations of net revenues of improved and local varieties clearly show important increases in the profitability of barley production resulting from the use of improved varieties. The net return of improved variety in Aarsal community exceeded that of local variety by 9% because of the increased yield of the improved variety (Table 6.11). Likewise, the use of improved variety resulted in increasing net revenue of barley production by 29% in Deir el Ahmar community, compared to that of the local variety. Data in Table 6.11 demonstrate that per unit area net revenue in Deir el Ahmar community for both local and improved varieties were higher than those of Aarsal community. This could be attributed to the increased barley yield in the former, because of the favorable weather conditions.

Another important factor in assessing the impact of a new technology is its neutrality. It is essential for an improved technology not to favor large farmers at the expense of small farmers. Therefore, the income distribution associated with the use of improved and local barley varieties needs to be investigated to draw some conclusions on the equity aspects of this technology. This was done by calculating the Gini coefficients of the net revenues for both improved and local varieties in both communities.

Table 6.11 **Production costs and revenues of local and improved barley varieties ($/dunum)**

Variety	Total revenue	Total cost*	Net revenue
Aarsal community			
Local	35.0	24.4	10.6
Improved	37.4	26.0	11.52
Deir el Ahmar community			
Local	61.7	27.5	34.2
Improved	69.0	24.7	44.4

** Total costs calculation included land rent and machinery fixed cost.*

Gini coefficient

The Gini coefficient is a value between zero and one that measures the degree of inequality in the distribution of income in a given society. The coefficient would register zero inequality (0.0 = minimum inequality) for a society in which each member received exactly the same income, and it would register a coefficient of one (1.0 = maximum inequality) if one member got all the income and the rest got nothing. The Gini coefficient is used in economics to measure income inequality.

The Gini coefficient is calculated as follows: arrange all the income groups into ascending order of income; for each group find its proportion Xi and those of the lower income groups into the whole population and the corresponding share Yi of income, for example, bottom 0.1 (X_1) has 0.01 (Y_1) income, bottom 0.3 (X_2) has 0.07 (Y_2) income, etc; then,

$$GC = 2*Covariance\ [Yt, F(y)/(Y)]$$

Gini coefficient can be calculated for any number of groups, and the groups may be of different sizes, e.g., four groups with proportions of 0.1, 0.3, 0.4, and 0.2 in the whole population. The calculated GC for Aarsal and Deir el Ahmar communities are presented in Table 6.12. Results indicate that the use of improved variety has greatly improved distribution of the net revenue of barley producers. For example, the GC of the income of barley producers in Aarsal variety reduced from 0.92 under the local variety to 0.26 under the improved variety. Similar conclusion applies on the improvement in the income distribution in Deir el Ahmar community due to the use of improved barley varieties. These findings are further explained by the Lorenz curve as in Figure 6.1.

Table 6.12 **The calculated Gini coefficients for improved and local barley varieties**

Community	Local variety	Improved variety
Aarsa	0.92	0.26
Deir Al Ahmar	0.22	0.11

Lorenz curve

Lorenz curve is a graphical representation of the degree of inequality of a in which the cumulative percentages of a population (e.g., taxpayers, firms) are plotted against the cumulative percentage of the variable under study (e.g., income, employment). A straight line rising at an angle of 45° from the start of the graph will indicate perfect equality. For instance, if 10% of firms employ 10% of the total labor force, 20% of firms employ 20% of the total labor force, and so on (see). However, if there are a large number of small firms that employ few people and a small number of large firms employing many people, the distribution will be unequal. When such a distribution is plotted, a curve will be traced below the 45° line and the degree of curvature will be greater with greater inequality. The calculated Lorenz curves using the net revenue data for barley producers planting improved and local barley varieties in Aarsal and Deir el Ahmar communities are depicted in Figures 9.1–9.4. These graphs provide additional support to the favorable equity implications due to the use of improved barley varieties.

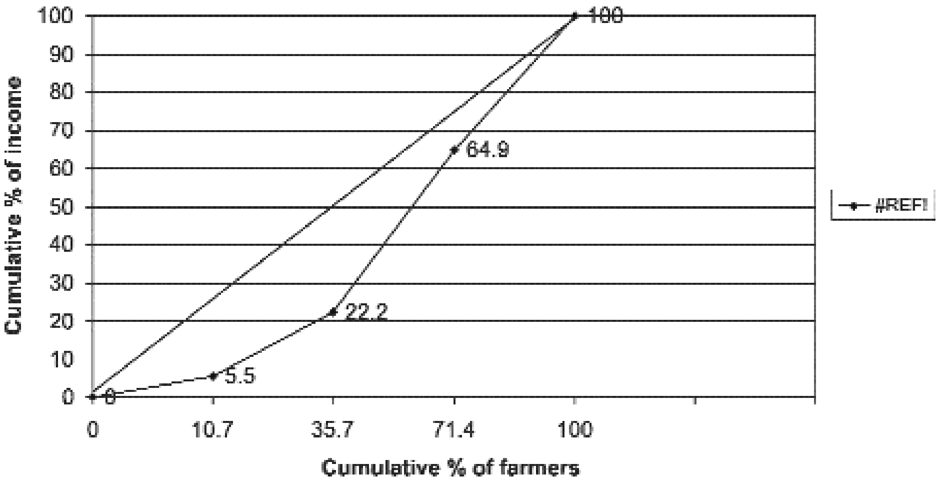

Figure 6.1 **Laurenz curve for local variety in Aarsal**

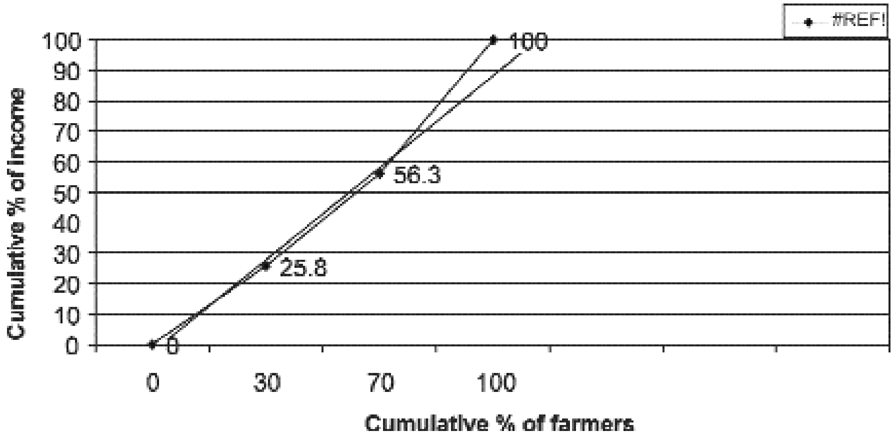

Figure 6.2 **Laurenz curve for improved variety in Aarsa**

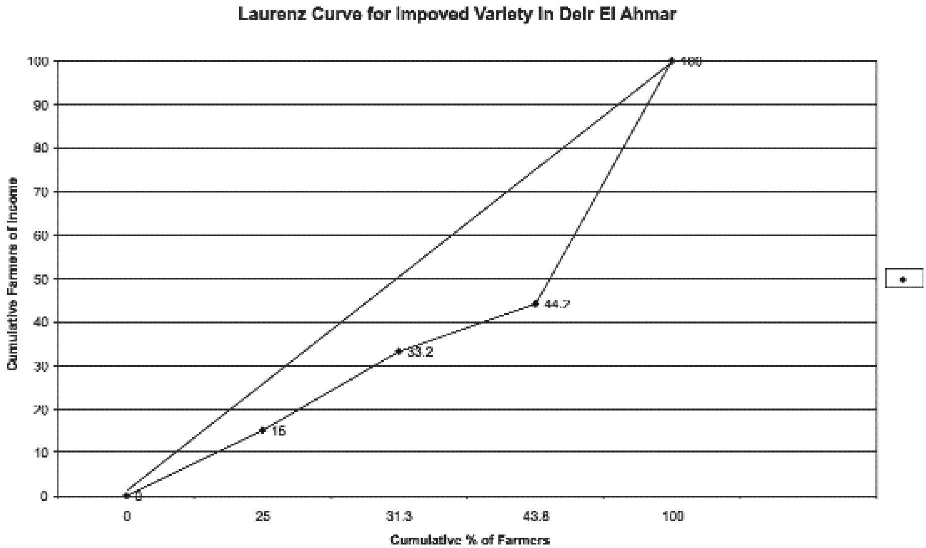

Figure 6.3 **Laurenz curve for improved variety in Deir El Ahmar**

Production function

The production function was used to measure the impact of improved barley on productivity. The use of production function will give the net impact of improved variety on barley productivity, compared to that of the local variety. Yield differences between the two varieties based on comparing farm data do not necessarily reflect the net yield advantage due to the biological characteristics of the improved variety, because some of the differences are attributed to the variation in the levels of input used. The production function in its general form is:

Y = f (X1, X2, X3, ... Xn)

Where Y refers to the total barley output, and Xs refer to the levels of variable inputs used in barley production. The results of the estimated production functions in a log form are presented in Tables 9.13 and 9.14.

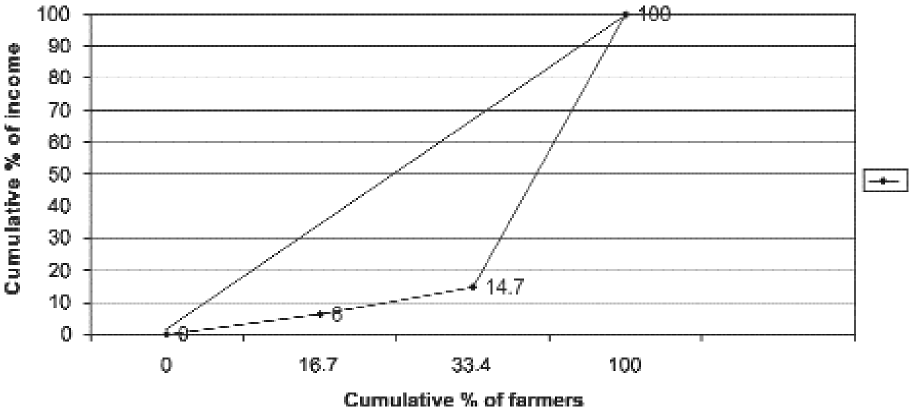

Figure 6.4 **Laurenz curve for local variety in Deir El Ahmar**

Table 6.13 **Estimated production function of improved varieties in Aarsal**

Model		Non-standardized coefficients		Standardized coefficients	t	Significance
		B	Std. error	Beta		
1	(Constant)	0.758	0.903		0.840	0.412
	LOGAREA	1.522	0.755	1.361	2.016	0.059
	LOGLABOR	0.937	0.660	1.116	1.419	0.173
	LOGMACHI	-1.768	1.207	-1.687	-1.464	0.160
	LOGAGE	-8.289E-02	0.169	-0.073	-0.492	0.629
	LOGSEED	2.500E-02	0.426	0.021	0.059	0.954
	LOGFERT	6.049E-02	0.204	0.074	0.296	0.771
	Adjusted R2	0.66				

Dependent variable: LOGPROD

Table 6.14 **Estimated production functions of improved varieties in Deir el Ahmar**

Model		Non-standardized coefficients		Standardized coefficients	t	Significance
		B	Std. error	Beta		
1	(Constant)	-2.190	8.248		-0.266	0.815
	LOGAREA	28.071	16.529	35.061	1.698	0.232
	LOGLABOR	-7.302	4.018	-8.464	-1.817	0.211
	LOGMACHI	-19.607	13.394	-23.924	-1.464	0.281
	LOGAGE	5.517E-02	2.606	0.015	0.021	0.985
	LOGSEED	-0.136	1.137	-0.169	-0.120	0.916
	LOGFERT	-2.395	1.263	-2.380	-1.896	0.198
	Adjusted R2	0.51				

Dependent variable: LOGPROD

Inclusion of a dummy variable on the use of improved variety in the production functions will allow isolation of the net impact of the improved varietal technology. Results of such exercise show that the net impact of the improved variety increased barley production by 19% in Aarsal community and 23% in Deir el Ahmar community (Table 6.15).

Table 6.15 **Total and net impacts of improved barley varieties (%)**

Type of impact	Aarsal community	Deir el Ahmar community
Total impact	30.0	35.5
Net impact	18.7	23.0

7

Adoption and Impact Studies in Morocco

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This study was conducted in the Khouribga and Settat Provinces (< 300 mm) of Morocco. The two communities are located within a semi-arid zone characterized by combined cereal and livestock production. The major cereals in this area are barley, bread wheat and durum wheat. Sheep production is very important throughout the area, followed by goats in Oued Zem district, which includes Ait Ammar community. The majority of farmers are considered as small since they operate on less than 10ha. Each farmer was formally interviewed using a questionnaire developed by the project team. The questionnaire included details on family members and their activities, crops and crop products, livestock, improved technologies, project contribution to their success, extension participation in the process of technology transfer and its role in diffusing information related to the technologies, and constraints facing large adoption of proposed technologies.

Sample for the study consisted of 81 farmers selected from two categories of producers. More than 60% of farmers were selected based on their participation in both Maghreb technology transfer and the M&M projects. The remaining 40% were chosen randomly from neighbors or farmers who benefited from a field day organized by the project in the region. The sample was developed in collaboration with extension workers of Khoribga and Settat, and local communities of Oued Zem and ElBrouj.

Barley Varieties

Adoption studies

The adoption rate of the new varieties of dual-purpose barley was around 45%, indicating that 45% of farmers were growing the three varieties introduced by the project (Table 7.1). Adoption rate varied according to farm size, sheep flock size and farmers' participation in technology transfer (TT) activities of the project. However, the percentage of barley area allocated to improved varieties was significant and represented 41% of the total. All large farmers adopted the new varieties but they allocated only 33% of their total barley area to them. The same figures were observed when we considered sheep production activity. The degree of adoption was about 40% of total barley area for small sheep producers. These differences can be explained by the risky behavior of the three categories of farmers.

Considering the degree of participation of farmers in the TT activities, it is clear that the high adoption rate was observed in the participant category. However, adoption degree was around 45% for non-participant farmers. This result is important in terms of the impact of the project in the region. With an adoption degree of around 39%, more effort is needed on diffusion to reach the 98% level observed for durum wheat and 78% for bread wheat.

The majority of farmers reported purchasing their barley seed annually. The most important constraints farmers faced were related to seed. Non-availability and high prices of seed were the major handicaps to adopting new barley varieties (Table 7.2). Farmers appreciated the grain quality and straw of the local variety as animal feed. About 17% of them suggested that grain quality and straw yield should be considered by the barley variety improvement program of INRA.

Table 7.1 **Adoption indicators of dual-purpose barley varieties**

Strata	No. of farmers	% of farmers	% of total area	Adoption rate	Degree of adoption
Farm size					
≤ 10ha	6	17.10	10	33.33	41
10-20ha	27	77.20	81	44.44	40
> 20 ha	2	5.70	9	100.00	33
Total	35	100	100	45.71*	39.77*
Sheep flock size					
≤ 10hr	9	25.70	10	55.55	40
10-30hr	18	51.40	42	38.89	43
> 30hr	8	22.90	48	50.00	32
Total	35	100	100	45.72*	39.71*
Farmers' participation					
Participant	13	37.10		100.00	38.11
Non-participant	22	62.90		13.64	45.37
Total	35	100		45.68*	42.68*

** Weighted averages of adoption rates and degree of adoption*

Table 7.2 **Constraints to adoption of improved barley varieties**

Constraints	Frequency	% of farmers
Low straw yield	4	11
Poor grain quality	4	11
Non-suitability for grazing	2	6
Non-availability of seed	5	14
High certified seed price	8	23
Non-availability and high price of seed	6	17
Low straw yield and grain quality	6	17
Total	35	100

Economic impact
The barley grain and straw yields were different for local and improved varieties. Table 7.3 shows improved varieties offering 45% more grain yield than the local variety, and local variety offering 12% more straw yield than the improved variety.

Table 7.3 **Yield comparison of improved and local varieties**

Variety	Grain yield (t/ha)	Straw yield (t/ha)
Local	0.87	0.94
Improved	1.26	0.83
Change (%)	44.83	-11.70

Total production costs of using new varieties of barley were higher than those of local varieties (Table 7.4). This could be attributed to the higher seed price. However, improved varieties generated an extra income of around 51$/ha, which could be attributed to the variation in production quantities between the varieties. The marginal rate of return was about 3.62, indicating that each dollar invested in the use of the improved varieties generated additional US$3.62.

Table 7.4 **Economic impact of adopted barley varieties**

Variety	Total cost ($/ha)	Gross margin ($/ha)	Net benefit ($/ha)	Marginal cost ($/ha)	Marginal benefit ($/ha)	Marginal rate of return
Local	112.17	228.05	115.88			
Improved	126.13	292.57	166.43	13.96	50.55	3.62
Change (%)	12.45	28.29	43.62			

Analysis of the income distribution among farmers showed that the Ginni coefficient was about 0.13 and 0.14, respectively, for local and improved varieties. Adoption of modern varieties did not affect the equity indicator. Small, medium and large farmers equally benefited from the use of modern varieties. In terms of income equity, both varieties were accepted.

Econometric analysis of the grain and straw production functions showed that both improved and local varieties had different net impact on straw and grain production. The local variety contributed more to straw production while the modern variety produced more grain. The estimated coefficients are presented in Tables 10.5 and 10.6.

Table 7.5 **The grain production function**

Independent variables	Coefficient	Standard error	Significance	R^2
Constant	0.948	0.574	S	50%
Ln area	1.138	0.655	S	
Ln machinery	0.244	0.190	NS	
Ln seed	-0.079	0.178	NS	
Ln nitrogen	-0.004	0.105	NS	
Ln labor	0.145	0.303	NS	
Variety	0.301	0.249	NS	

S = significant at 0.05; NS = not significant

Table 7.6 **Straw production function**

Independent variables	Coefficient	Standard error	Significance	R^2
Constant	2.074	0.100	HS	60%
Ln area	-0.034	0.114	NS	
Ln machinery	-0.012	0.033	NS	
Ln seed	0.014	0.031	NS	
Ln nitrogen	0.020	0.018	NS	
Ln labor	0.050	0.053	NS	
Variety	-0.110	0.049	S	

S = significant at 0.05; NS = not significant; HS = significant at 0.01

The net impact of the modern variety on grain production was around 35%, indicating that the improved variety contributed only about 35% to the improvement of grain production. However, the net impact of the modern variety on straw production was negative. The use of modern variety contributed to total straw production loss of 11%. Comparing this figure to the variation observed at the farm level, it is clear that the reduction was entirely due to the use of improved varieties.

In terms of feed security, the linear regression model showed that modern varieties contributed about 175kg/head/year (Table 7.7), which was about 75% of the total forage units needed by each small ruminant (standard flock). The farm size affected positively the barley contribution to small ruminant feed security. If we increase the area by about one unit, the feed security would increase by about 0.10. However, varietal contribution was positive, about 18%. The flock size was negatively correlated to animal feed security.

Table 7.7 **Feed security**

Functions	Coefficient	Standard error	Significance	R^2
Constant	1.766	0.450	HS	34%
Variety	0.175	0.433	NS	
Labor	0.002	0.032	NS	
Square area	0.103	0.072	S	
Head small ruminants	-0.052	0.012	HS	

S = significant at 0.05; NS = not significant; HS = significant at 0.01

Feed blocks

The impact evaluation of feed blocks was conducted at Sidi Boumehdi community (ElBrouj area). The adoption rate of feed blocks was much higher in the large herders' category (Table 7.8). This represented 69% of the total population of sheep. However, only 80% of total livestock producers adopted the feed block technology.

Table 7.8 **Adoption of feed block technology**

	Number of farmers	% of farmers	% of sheep population	Adoption rate
Sheep flock size				
≤ 10hd	10	32.26	6.65	20.00
10-30hd	10	32.26	24.11	20.00
> 30hd	11	35.48	69.24	54.55
Total	31	100	100	32.26
Farmers' participation				
Participant	10	32.26	80.00	
Non-participant	21	67.74	9.52	
Total	31	100.00	32.26	

Constraints to the adoption of feed block technology were related to the ingredients used, essentially cement. More than 70% of farmers were not convinced about the utility of cement. All the farmers appreciated the feed blocks formula, but they did not use cement; therefore, feed blocks were not made. The production cost was about 1.30DH/kg (US$0.12), and was acceptable by farmers.

It is necessary to mention that farmers used feed blocks to improve feeding systems and fattening practices at low cost. However, the objective of researchers by introducing feed blocks was to maintain animal live weight or at least minimize weight loss during stubble grazing and drought. They consider feed blocks as supplemental feed.

Impact Assessment of Fodder Shrubs

For this evaluation, we used 625kgDM/ha as the average productivity from a plant density of 1,000 plant/ha. The total cost of planting one hectare was about US$106.09 including costs of seed, family labor, irrigation and guarding. The discount rate used was modest (around 10%). The period used for the analysis was 15 years and the dry matter price equivalent was US$0.23/kg. Results are reported in Table 7.9.

As the table indicates, the production of fodder shrubs was profitable. An IRR of 48% implies that if the farmers had to borrow the funds invested in *Atriplex* production over a 15-year period at an interest rate of 48.0%, the benefits generated would be sufficient to repay the principal and accrued interests of such a loan. The net present value of the stream of expenditures and returns over the period was US$733/ha. Moreover, the calculated benefit/cost ratio of 8:1 indicates that every dirham invested in *Atriplex* production over the same period yielded a social benefit of 8 dirhams. Therefore, although the estimated IRR may not compare favorably with previous rates reported in the region and elsewhere, it nevertheless represents a good return to investment. The high B/C ratio was a result of the substantial benefits generated by *Atriplex* production with relatively modest costs.

For alley-cropping technology, we used the results of the experiments conducted at the Aridoculture Center (Chriyaa and ElMzouri, 1996–1999). The rows of *Atriplex nummularia* shrubs at an average plant density of 333 plants/ha were associated with barley as a forage crop. Barley was planted during early November, with a seeding rate of about 160kg/ha, and the varieties used were similar to those used by farmers (ACSAD, local).

Results of biomass production under alley-cropping system with *Atriplex nummularia* shrubs and the other coefficients are presented in Table 7. Dry matter production obtained for all fodder shrubs was significantly high in comparison to farmers' mono-cropping system.

Data in Table 10 indicate that alley-cropping system is more profitable than mono-cropping. An IRR of 79% implies that if the farmers had to borrow the funds invested in *Atriplex*-barley production over a 15-year period at an interest rate of 79%, the benefits generated would be sufficient to repay the principal and accrued interests of such a loan. The net present value of the stream of expenditures and returns over the period amounted to US$3342.5/ha. Moreover, the calculated benefit/cost ratio of 6:1 indicates that every dollar invested in alley-cropping technology over the same period yielded a social benefit of US$6.

Impact Assessment of Cactus Technology

In semi-arid regions (200–350mm), it is recommended to plant cactus between March and April, with an average plant density of around 300 plants/ha. Closer spacing is used for the open vase in very poor soils. Cladode cuttings are used for planting, and each cladode costs about US$0.09. Pre-planting applications of 4–6 ton/ha of manure and two irrigations are required for successful establishment. The average price of manure is about US$8–10/t. Total cost of planting (including labor), returns and biomass production are reported in Table 7.11.

Table 7.9 **Returns on investment in shrub planting**

Year	Land area (ha)	Biomass (kg/ha)	Value ($/kg DM)	Gross return ($/ha)	Nominal cost ($/ha)	Discounting coef.	Actual cost ($/ha)	Disc. return ($/ha)	Net Benefit ($/ha)
0	1	0.00	0.23	0.00	106.09	1.0000	106.09	0.00	-106.09
1	1	0.00	0.23	0.00	0.00	0.9091	0.00	0.00	0.00
2	1	0.00	0.23	0.00	0.00	0.8264	0.00	0.00	0.00
3	1	655.00	0.23	148.86	0.00	0.7513	0.00	111.84	111.84
4	1	655.00	0.23	148.86	0.00	0.6830	0.00	101.68	101.68
5	1	655.00	0.23	148.86	0.00	0.6209	0.00	92.43	92.43
6	1	655.00	0.23	148.86	0.00	0.5645	0.00	84.03	84.03
7	1	655.00	0.23	148.86	0.00	0.5132	0.00	76.39	76.39
8	1	655.00	0.23	148.86	0.00	0.4665	0.00	69.45	69.45
9	1	655.00	0.23	148.86	0.00	0.4241	0.00	63.13	63.13
10	1	655.00	0.23	148.86	0.00	0.3855	0.00	57.39	57.39
11	1	655.00	0.23	148.86	0.00	0.3505	0.00	52.18	52.18
12	1	655.00	0.23	148.86	0.00	0.3186	0.00	47.43	47.43
13	1	655.00	0.23	148.86	0.00	0.2897	0.00	43.12	43.12
14	1	655.00	0.23	148.86	0.00	0.2633	0.00	39.20	39.20
							106.09	838.27	732.18
					B/C = 8				
					IRR = 43%				

Table 7.10 **Returns on investment in alley cropping**

Period (yrs)	Land area (ha)	Y (kg/ha)	P ($/kg DM)	B ($/ha)	C ($/ha)	Discount coefficient	Dis. cost ($/ha)	Dis. benefit ($/ha)	Net Benefit
0	1	0.00	0.18	0.00	159.00	1.0000	159.00	0.00	-159.00
1	1	0.00	0.18	0.00	0.00	0.9091	0.00	0.00	0.00
2	1	0.00	0.18	0.00	0.00	0.8264	0.00	0.00	0.00
3	1	3762.00	0.18	684.00	100.00	0.7513	75.13	513.90	438.77
4	1	3866.80	0.18	703.05	100.00	0.6830	68.30	480.20	411.89
5	1	4024.00	0.18	731.64	100.00	0.6209	62.09	454.29	392.20
6	1	4024.00	0.18	731.64	100.00	0.5645	56.45	412.99	356.54
7	1	4024.00	0.18	731.64	100.00	0.5132	51.32	375.45	324.13
8	1	4024.00	0.18	731.64	100.00	0.4665	46.65	341.31	294.66
9	1	4024.00	0.18	731.64	100.00	0.4241	42.41	310.29	267.88
10	1	4024.00	0.18	731.64	100.00	0.3855	38.55	282.08	243.52
11	1	4024.00	0.18	731.64	100.00	0.3505	35.05	256.43	221.38
12	1	4024.00	0.18	731.64	100.00	0.3186	31.86	233.12	201.26
13	1	4024.00	0.18	731.64	100.00	0.2897	28.97	211.93	182.96
14	1	4024.00	0.18	731.64	100.00	0.2633	26.33	192.66	166.33
							722	4064.64	3342.53

B/C = 6
IRR = 79%

Table 7.11 **Returns on investment in cactus technology**

Period	**Yield (BM) (t/ha)**	**Price ($/t)**	**Fruit (t/ha)**	**Fruit price ($/t)**	**Benefits ($/ha)**	**Cost ($/ha)**	**Discount coefficient ($/ha)**	**Discounted cost ($/ha)**	**Discounted benefit**	**Net Benefit**
0	0.00	0.00	0.00	0.00	0.00	853.10	1.00	853.10	0.00	-853.10
1	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.00	0.00	0.00
2	0.00	0.00	0.00	0.00	0.00	0.00	0.75	0.00	0.00	0.00
3	3.00	7.08	4.00	40.0000	181.24	30.40	0.75	22.84	136.17	113.33
4	5.00	7.08	7.00	40.0000	315.40	30.40	0.68	20.76	215.42	194.66
5	8.00	7.08	10.00	40.0000	456.64	30.40	0.62	18.88	283.54	264.66
6	8.00	7.08	10.00	40.0000	456.64	30.40	0.56	17.16	257.76	240.60
7	8.00	7.08	10.00	40.0000	456.64	30.40	0.51	15.60	234.33	218.73
8	6.00	7.08	8.00	40.0000	362.48	30.40	0.47	14.18	169.10	154.92
9	6.00	7.08	8.00	40.0000	362.48	30.40	0.42	12.89	153.73	140.83
10	5.00	7.08	7.00	40.0000	315.40	30.40	0.39	11.72	121.60	109.88
11	5.00	7.08	7.00	40.0000	315.40	30.40	0.35	10.66	110.55	99.89
12	5.00	7.08	7.00	40.0000	315.40	30.40	0.32	9.69	100.50	90.81
13	4.00	7.08	6.00	40.0000	268.32	30.40	0.29	8.81	77.72	68.92
14	4.00	7.08	6.00	40.0000	268.32	30.40	0.29	0.00	70.66	70.66
								1016.28	1931.07	914.79

B/C = 2

IRR = 11%

Data in Table 7.11 indicate that cactus planting was less profitable than fodder shrubs. However, in addition to the economic impact, cactus has a positive environmental impact by protecting the soil. This aspect was not evaluated by the team. An IRR of 11% implies that if the farmers had to borrow the funds invested in cactus over a 15-year period at an interest rate of 11%, the benefits generated would be just sufficient to repay the principal and accrued interests of such a loan. The net present value of expenditures and returns over the period was US$915/ha. Moreover, the calculated benefit/cost ratio of 2:1 indicates that every dollar invested in cactus technology over the same period yielded a social benefit of US$2.

Conclusions

For more than eight years, a large number of sheep producers were involved in the M&M Project's technology transfer, demonstration and extension activities. Several experiments were conducted on-station and on-farm to evaluate the potential of the M&M-promoted technologies.

Adoption evaluation of improved barley varieties showed that more than 45% of farmers have adopted the new varieties. The adoption rate ought to be more than 90%, given the importance of the project activities and the activities of government. However, farmers' opinions revealed many constraints related to the adoption of improved varieties. These include seed price and availability, which is an important institutional problem that needs more involvement of policy-makers. With a marginal rate of return of about 362%, improved varieties are more profitable than the local ones. Nevertheless, the importance of livestock makes farmers to allocate more area to planting local varieties because of straw production and quality. This needs to be carefully considered by barley breeders.

Economic evaluation of the feed block technology showed that the adoption rate was still low in comparison to the efforts devoted to it by the government and researchers. With an average adoption rate of 33%, it seems that the technology requires more efforts in formulation and extension. In addition, the objectives of the technology are not yet properly understood.

The economic assessment of fodder shrubs and alley-cropping showed that both technologies are economically profitable and should be extended on a large scale into agro-pastoral areas. These technologies were recently introduced and need more government support in form of plant subsidies and reserve compensation to help farmers and communities that are adopting these technologies.

Farmers are already using cactus, especially for fruit production, but evaluation of the new ecotypes shows that economic performances are not significant in comparison to fodder shrubs. However, according to specialists, cactus generates positive environmental externalities, which are difficult to evaluate at this stage.

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8

Adoption and Impact Studies in Syria

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Introduction

The MM Project in Syria was jointly implemented by the Ministry of Agriculture and Agrarian Reform and ICARDA. In its second phase, 1998–2002, the main objective of the project was to transfer new technologies to targeted communities to increase their income and welfare. The new technologies introduced by the project included improved variety of barley, introduction of forage legumes in the crop rotation, treated straw, early weaning, harmonic sponge, feed blocks, and improved rams. A socioeconomic study was conducted in collaboration with ICARDA to examine the achievements of the project in technology adoption and to analyze the impact of the most important technologies on household income.

The project transferred a package of technologies in cooperation with NGOs, e.g., farmers' associations, public agencies such as extension units, and farmers in the region. Two communities were selected as project sites in Syria. The first community was Om Al Amad in Hama Province, representing zones 2 and 3. The second community was Al Mahmoudly in Al Raqqa Province, representing zones 4 and 5.

The study was based on data collected for two seasons, 2000/2001 and 2001/2002, through rapid rural appraisal. Primary data were collected from 95 households using a questionnaire. Fifty nine and 36 households were selected randomly from Om Al Aamad and Al Mahmoudly respectively. The sample included three household groups, namely, participants in the project, non- participants within the community and non-participants from outside the community.

Diffusion Process

Diffusion of new technologies is directly linked to adoption process. According to the diffusion theory, the adoption of a new technology is not a single sudden event, but it is a process. The diffusion of an innovation has been defined as a process by which the innovation is communicated through certain channels over time among members of a social system (Rogers, 1983). A social system is defined by Rogers (1983) as "a population of individuals who are functionally differentiated and engaged in collective problem-solving behaviour". In the context of this study, the social system consists of the potential adopters or farming communities in the target areas.

The time dimension is essential in the diffusion process; it is an important aspect of any communication process. Researchers (Rogers, 1983; Mahajan and Peterson, 1985; CIMMYT, 1993) have shown that adoption of an innovation often follows a normal distribution curve when plotted against time. If the cumulative number of adopters is plotted over time, the resulting distribution is an S-shaped curve, in which there is slow initial growth in the use of the new technology, followed by a more rapid increase, and then a slowing down as the cumulative percentage of adoption approaches its maximum. Early research on the diffusion process focused on describing the observed diffusion patterns in terms of pre-specified distributions (Mahajan and Peterson, 1985). Subsequent research has attempted to develop more theory-based models. Diffusion models have been developed to represent the spread of an innovation amongst a given population of prospective adopters in terms of a simple mathematical function of the time that has elapsed from the introduction of the innovation. The objective of such a diffusion model is to show the successive increase in the number of adopters over time. This provides valuable information about trends and prospects for a new technology, by providing an estimate of the rate of adoption, from which predictions about future progress and demand for inputs can be made. In addition, it allows extension services to quantify the change in the number of technology users over time in order to evaluate the impact of an agricultural technology (CIMMYT, 1993).

Logistic function has been used in this research, a well-known function in determining the level of adoption of new technologies. The function is S shaped (Mazid et al, 1999). It is expressed as follows:

$$Y_t = K / (1+ e^{-z-xt})$$

Where: Y_t = cumulative share of the adopter in time t

K = the maximum adoption rate

X and Z = constants

The function could be written as follows:

$$k = y_t(1 + e^{-z-X_t})$$

$$k = y_t + y_t e^{-z-X_t}$$

$$\frac{k - y_t}{y_t} = e^{-z-X_t}$$

$$\frac{y_t}{k \quad y_t} = e^{z + X_t}$$

$$\ln \frac{y_t}{k - y_t} = z + X_t$$

The constants can be calculated by using regression analysis.

Results and Discussion

Diffusion of improved barley varieties

Adoption

a. Om Al Amad community

The adoption rate of the improved barley varieties for the whole sample was about 34.5%, 90% of whom were participants in the M/M project and the remaining 10% were non-participants (*Table 8.1*).

Table 8.1 **Adoption rate of improved barley varieties, Om Al Amad (%)**

	Participants	Non-participants from the community	Non-participants from outside the community	Total
Non-adopters	26	32	41	100
Adopters	90	10	0	100

Calculated and elaborated from the survey

Logistic function was used to estimate the maximum adoption rate of the improved barley. It is expressed as follows:

$$y_t = \frac{k}{(1 + e^{-1008.421 - 0.504 * year})}$$

Where: Y_t = cumulative share of the adopter in time t

K = maximum adoption rate

Based on this function, the adoption rate curve can be drawn as shown in Figure 8.1. It shows that the diffusion of this technology will continue in the future, while the expected adoption rate will reach 75% in 2006.

b. Al Mahmoudly community

Barley adoption rate in Al Mahmoudly was nearly 44% of total households, all of whom were participants in the M/M Project (Table 8.2).

Table 8.2 **Adoption rate of improved barley varieties, Al Mahmoudly community (%)**

Item	Participants from the community	Non-participants from outside the community	Non-participants	Total
Non-adopters	39	22	39	100
Adopters	100	0	0	100

Calculated and elaborated from the survey

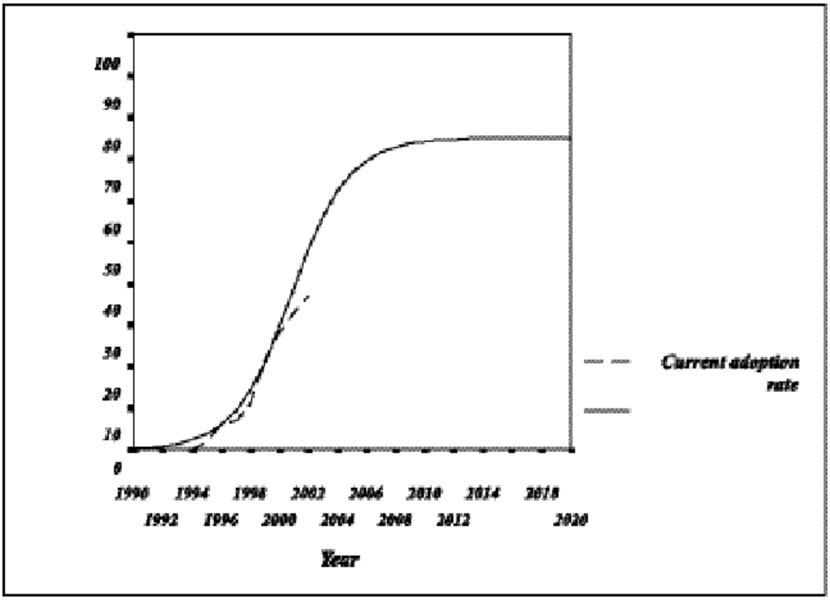


Figure 8.1 **Current and expected adoption rates of improved barley varieties, Om Al Amad community**

In 2007, the expected adoption rate reached its maximum, 93%, and its function was expressed as follows:

$$y_t = \frac{k}{(1 + e^{-1008.421 - 0.504 * year})}$$

The curve of the adoption is as shown in Figure 8.2.

Constraints to the adoption of improved barley varieties
a. Om Al Amad community
Barley is cultivated widely in Om Al Amad community. It formed about one third of the cultivated areas, but only 34% of the total households used the improved barley varieties, while the rest gave reasons for not cultivating them.

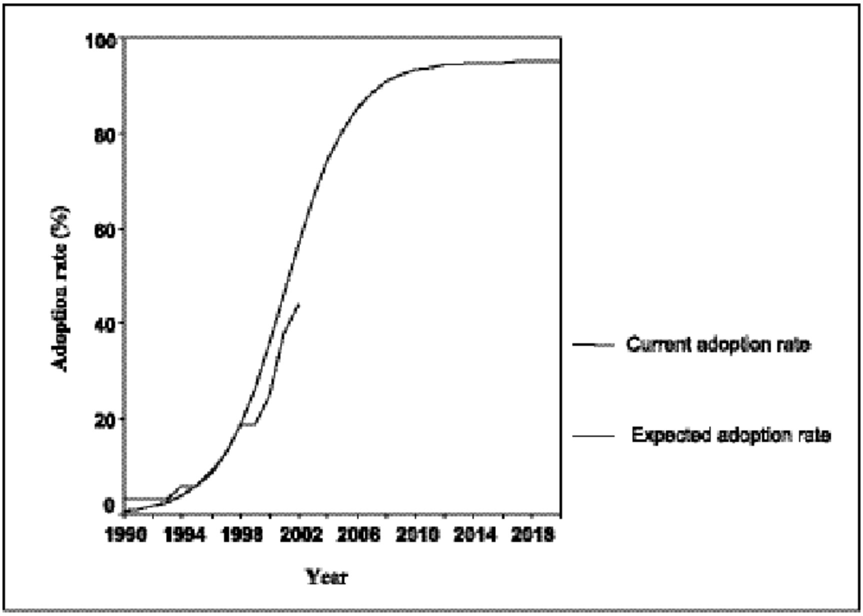
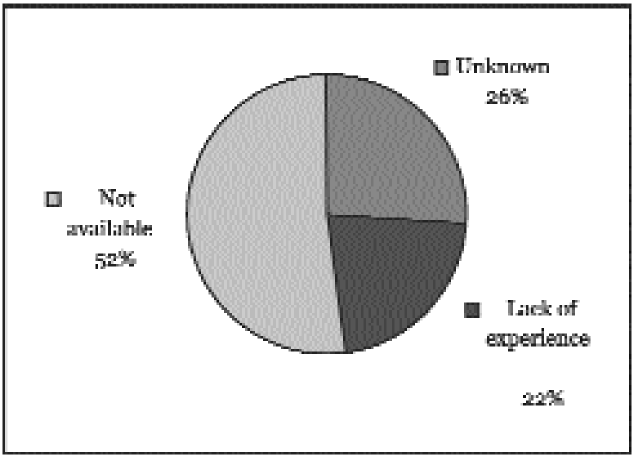


Figure 8.2 **Current and expected adoption rates of improved barley varieties, Al Mahmoudly community**



Calculated and elaborated from the survey

Figure 8.3 **Major constraints to the adoption of improved barley varieties, Om Al Amad community**

b. Al Mahmoudly community

Barley occupied more than 50% of the total cultivated areas under barley in this community; however, only 44% of the households adopted improved barley varieties. The improved barley varieties did not meet the desire of the non-adopter households because of the color, price, and others reasons (Figure 8.4).

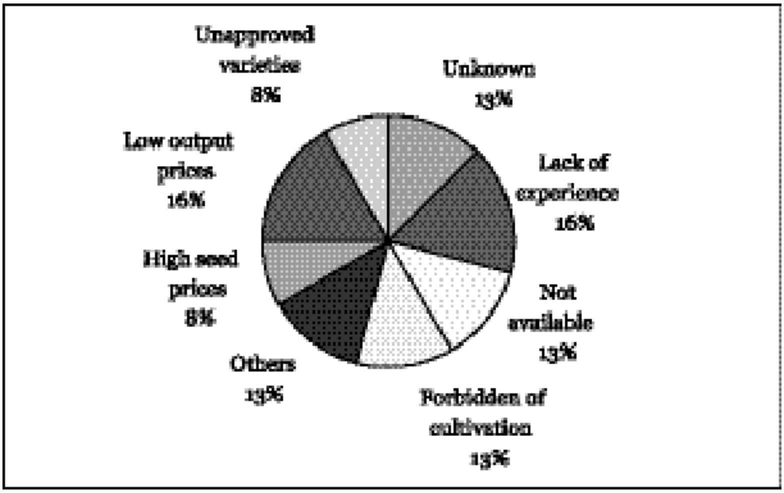


Figure 8.4 **Major constraints to the adoption of improved barley varieties, Al Mahmoudly community**

Diffusion of introducing forage legumes technology
Introduction of forage legumes into barley/barley crop rotation system was new to the communities. The technology increases availability of livestock fodder and improves soil fertility so as to increase livestock production from milk and meat.

Adoption of introducing forage legumes
a. Om Al Amad community
Some of the non-participant households from this and neighboring communities adopted the introduction of forage legumes technology. They did so because they recognized its benefits (Table 8.3).

Table 8.3 **Distribution of adopters and non-adopters according to their participation in the project, Om Al Amad community (%)**

Item	Participants	Non-participants from the community	Non-participants from outside the community	Total
Non-adopters	37	26	37	100
Adopters	82	18	0	100

The adoption rate of introducing forage legumes technology was 30% of households in the community and the maximum expected adoption rate was 90%. The diffusion function is expressed as follows:

$$y_t = \frac{k}{(1 + e^{-432.178 - 0.216 * year})}$$

The diffusion process will continue and will reach the maximum expected adoption rate (90%) in 2012 (Figure 8.5).

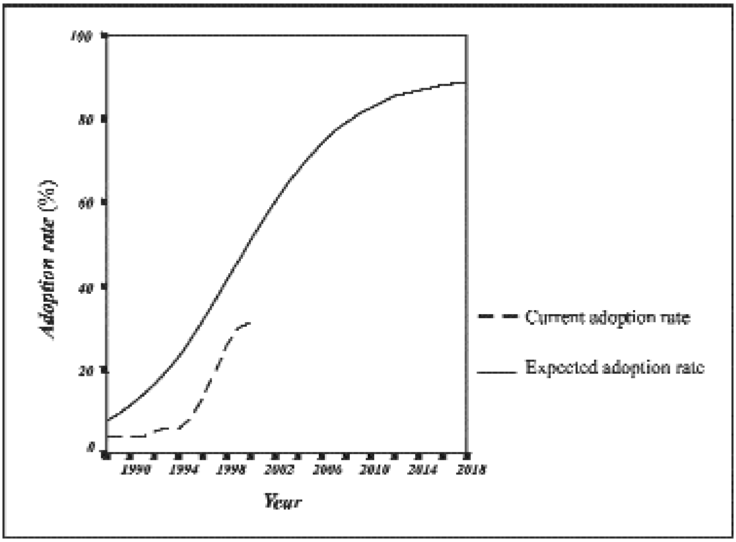


Figure 8.5 **Current and expected adoption rates of introducing forage legumes in Om Al Amad community**

b. Al Mahmoudly community

The adoption rate of introducing forage legumes into agricultural rotation was low even among participants in the project. This was due to: (a) non-availability of large areas under barley, which would be more appropriate for livestock feeding; (b) non-availability of forage legumes seed; and (c) unwillingness of some households to change their rotation.

Table 8.4 **Distribution of adopters and non-adopters according to participation in the project, Al Mahmoudly community (%)**

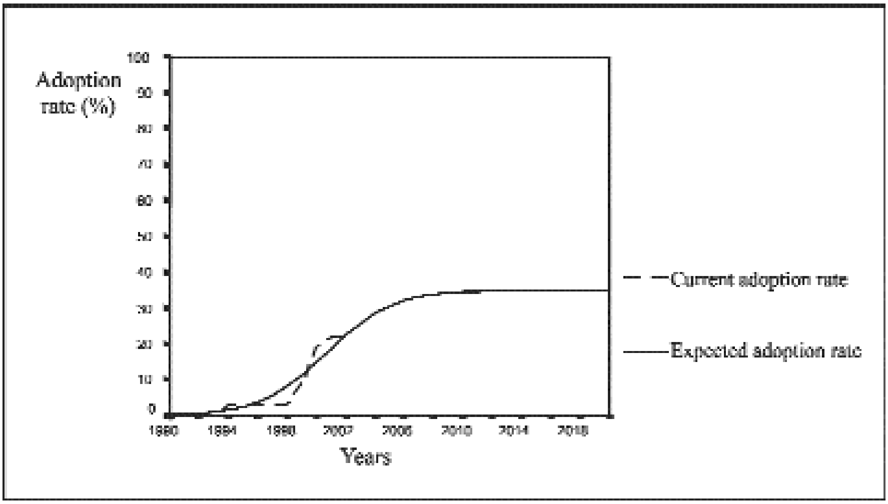
Item	Participants	Non-participants from the community	Non-participants from outside the community	Total
Non adopters	62	14	24	100
Adopters	100	0	0	100

Calculated and elaborated from the Survey

Current adoption rate of this technology was about 20% of the households, while the expected adoption rate was 35%. The function of the adoption rate is expressed as follows:

$$y_t = \frac{k}{(1 + e^{-888.3 - 0.444 * year})}$$

The cumulative adoption curve is as shown in Figure 8.6.



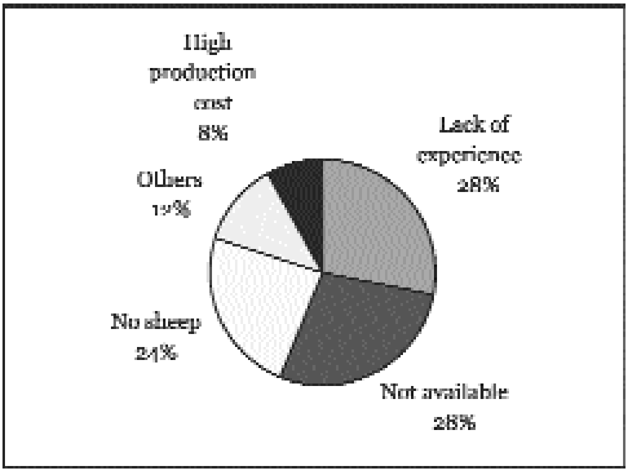
Calculated and elaborated from the Survey

Figure 8.6 **Current and expected adoption rates of introducing forage legumes in agricultural rotation, Al Mahmoudly community**

Constraints to the adoption of forage legumes technology

a. Om Al Amad community

According to the formal survey, the main constraints to the adoption of introducing forage legumes into agricultural rotation were, non-availability of seeds, lack of experience, and others as shown in Figure 11.7.

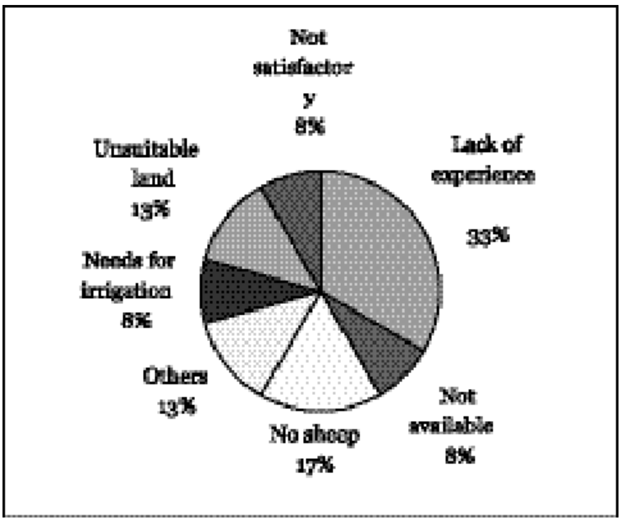


Calculated and elaborated from the survey

Figure 8.7 **Constraints to the adoption of introducing forage legumes to agricultural rotation, Om Al Amad community**

b. Al Mahmoudly community

Lack of experience in cultivating forage legumes was the major obstacle to the adoption of the technology, in addition to other reasons (Figure 8.8).



Collected and elaborated from the survey

Figure 8.8 **Constraints to the adoption of introducing forage legumes to agricultural rotation, Al Mahmoudly community**

Diffusion of early weaning technology
Early weaning technology results in the production of more milk for the market, but it requires providing lambs with concentrated feed.

Adoption of early weaning
a. Om Al Amad
The adoption rate of this technology was very low and the adopters were only participants in the project. The adoption rate in Om Al Amad was 20% of total households in the community and 33% of total households that participated in the M/M project.

Table 8.5 **Distribution of adopters and non-adopters of early weaning according to participation in the project, Om Al Amad community (%)**

Item	Participants	Non-participants from the community	Non-participants from outside the community	Total
Non-adopters	50	12	38	100
Adopters	100	0	0	100

Calculated and elaborated from the survey

b. Al Mahmoudly community
Adoption rate of early weaning in Al Mahmoudly was generally very low, 10% and 15% among total households and households that participated in the project respectively (Table 8.6)

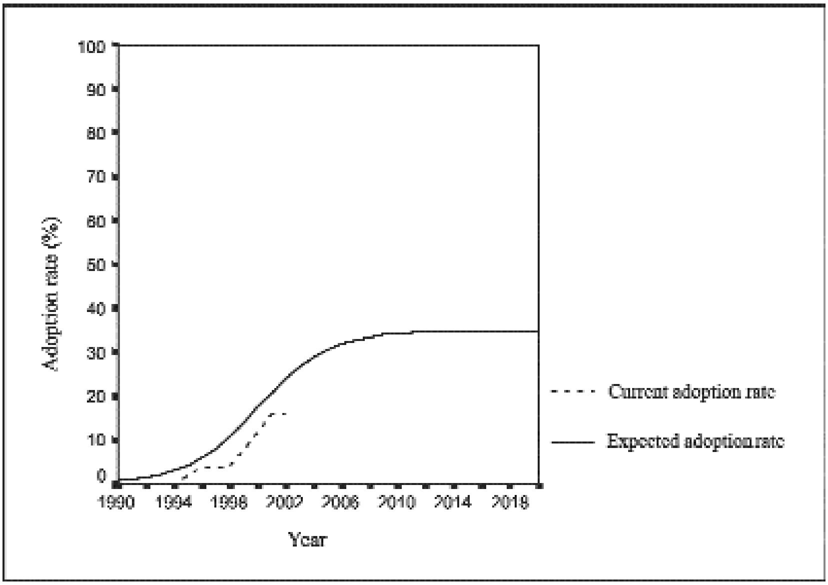
Table 8.6 **Distribution of adopters and non-adopters of early weaning according to participation in the project, Al Mahmoudly community (%)**

Item	Participants	Non-participants from the community	Non-participants from outside the community	Total
Non-adopters	58	16	26	100
Adopters	100	0	0	100

Calculated and elaborated from the survey

Because of the low adoption rate, the curves of the adoption for both communities were drawn on one graph (Figure 8.9). The maximum expected adoption rate was 35% and the function is expressed as follows:

$$y_t = \frac{k}{(1 + e^{782 - 0.391 * year})}$$

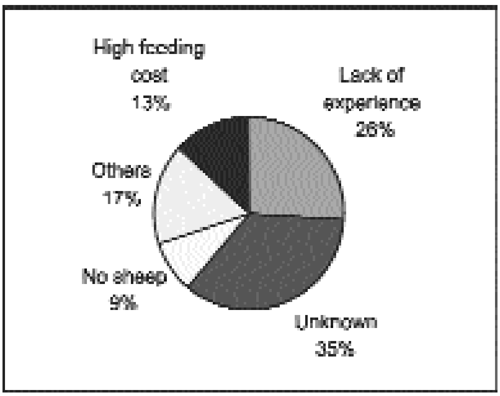


Calculated and elaborated from the survey

Figure 8.7 **Constraints to the adoption of introducing forage legumes to agricultural rotation, Om Al Amad community**

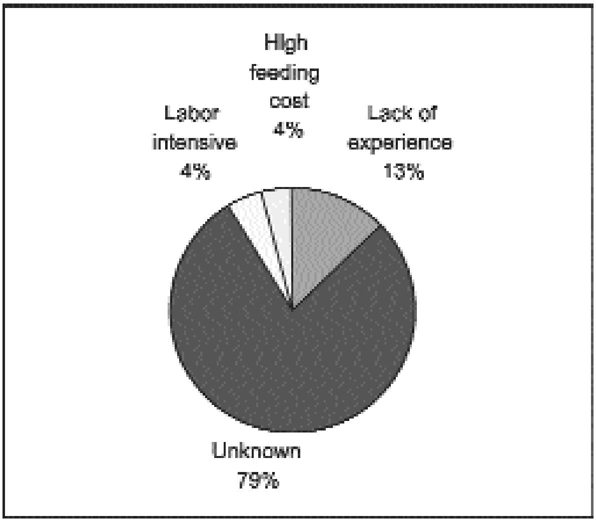
Constraints to the adoption of early weaning

The major constraints of adopting early weaning technology in both communities included ignorance of the technology, lack of experience in using it, high feeding cost, lack of space for the weaned lambs (Figures 11.10 and 11.11).



Collected and elaborated from the survey

Figure 8.10 **Constraints to the adoption of early weaning, Om Al Amad community**



Collected and elaborated from the survey

Figure 8.11 **Constraints to the adoption of early weaning, Al Mahmoudly community**

Effects of the Mashreq/Maghreb Project on Household Income

This research has studied the effects of the Mashreq/Maghreb (M/M) Project by exploring the impact of each technology introduced by the project on the income of rural families in the target communities. The study classified the effects according to community, adoption behavior, settlement zone, and livelihood standard.

Effects of improved barley varieties

By community

The improved barley varieties contributed more to an increase in the income of households in 2001 than 2002 in Om Al Amad community. The reverse was however the case in Al Mahmoudly community (Table 8.7).

Table 8.7 **Contribution of the improved barley varieties to the increase in income in the target communities (Syrian pounds, SP)**

Community	2000/2001	2001/2002
Om Al Amad	2929	765
Al Mahmoudly	5122	15,892

Calculated and elaborated from the survey

The difference between the two seasons was due to a difference in size of the harvested area of improved barley. In Om Al Amad community, the harvested area under improved barley varieties was 601 *donum* in 2001 but decreased to 335 *donum* in 2002, because some households substituted part of their cultivated barley area with cumin. In addition, the decrease in yield by 40kg/*donum* contributed to a decrease in the effect of this technology on household income. In Al Mahmoudly community, the area increased from 1470 *donum* in 2001 to 2050 *donum* in 2002. Statistical analysis shows that the difference in income between the two communities was significant at 1%.

By adoption behavior

a. Om Al Amad community

The increase in income of adopters of the improved barley varieties was about 8017SP per household in 2001, whereas it was 2257SP per household in 2002. This difference was due to a decrease in area under barley cultivation and yield in the second season, as mentioned earlier (Table 8.8). The difference between the average income of adopting and non-adopting families of the improved barley technology was significant at 1% in the first and 4% in the second seasons. There was no effect of this technology on non-adopting families.

Table 8.8 **Contribution of improved barley varieties to the increase in income of households according to adoption behavior, Om Al Amad community (SP/household)**

Adoption status		2000/2001	2001/2002
Non-adopters	Average	366.9	0
	SD	1314	0
Adopters	Average	8017	2257
	SD	16,556	6577
Average	Average	3200	836
	SD	10,641	4089

Collected and elaborated from the Survey

b. Al Mahmoudly community

Increase in household income for adopters of improved barley was about 13,105 SP in 2001, whereas it was 39,507 SP in 2002. As mentioned earlier, this was because of the increase in harvested area under barley in the second season (Table 8.9). There was a significant difference in the increase in average income between adopters and non-adopters at 3% in the first season and 1% in the second season. The technology slightly affected non-adopters in 2001, but did not have any effect in 2002.

By agro-ecological zone

a. Om Al Amad community

The study covers only one zone in Om Al Amad community, which is settlement zone 2. Increase in household income was about 2929SP in the first season and 765SP in the second season.

b. Al Mahmoudly community

The effect of improved barley varieties on household income differed according to settlement zones. The highest increase was in zone 2 in the 2001/2002 season. This is normal because the areas under improved barley in zones 2 and 3 were almost equal, but the yield in zone 2 (186kg/donum) was more than that of zone 3 (172kg/donum) (Table 8.10).

Table 8.9 **Contribution of improved barley varieties to the increase in income of households according to adoption behavior, Al Mahmoudly community (SP/household)**

Adoption		2000/2001	2001/2002
Non-adopters	Average	51	0
	SD	218	0
Adopters	Average	13105	39507
	SD	24945	60334
Average	Average	5762	17284
	SD	17443	43852

Collected and elaborated from the Survey

Table 8.10 **Contribution of improved barley varieties to the increase in income of households according to settlement zones, Al Mahmoudly community (SP/household)**

Settlement zone	Item	2000/2001	2001/2002
2	Average	10,987	25,131
	SD	24,448	52,387
3	Average	1444	15,014
	SD	4902	38,714
4	Average	103	0
	SD	292	0
Total average	Average	5122	15,893
	SD	16,519	41,306

Collected and elaborated from the survey

By household livelihood

a. Om Al Amad community

Improved barley varieties contributed to the increase in income of most households in both seasons. It did not however contribute to any increase in income of upper intermediate households (Table 8.11).

Table 8.11 **Contribution of improved barley varieties to increase in income of households according to living standard, Om Al Amad community (SP/household)**

Living standard		2000/2001	2001/2002
Very poor	Average	1007	643
	SD	4697	1701
Poor	Average	166	0
	SD	526	0
Sufficient	Average	4319	1070
	SD	12,416	4822
Upper intermediate	Average	0 0	
	SD	0	0
Average	Average	2929	765
	SD	10,212	3916

Collected and elaborated from the survey

Improved barley varieties contributed to the increase in income of adopters with poor households by 2350SP in 2000/2001 season and 1500SP in 2001/2002 season. It also contributed to increase in income of sufficient adopter households by 9580SP in 2000/2001 season and 2540SP in 2001/2002 season. However, these differences were not significant. Analysis shows that sufficient households tried to increase their income by adopting new technologies, especially when the technology was simple and cheap. However, upper intermediate households did not care about new technologies either because their area was very large and required large amount of seed that is not easily available or they were busy increasing their income from other activities.

b. Al Mahmoudly community

The income of the sufficient households was positively affected when they applied the improved barley varieties, and the income of upper intermediate households was less affected than that of the poor households (Table 8.12). The sufficient households benefited more than others because they could afford the seeds, and they did not have other ways to increase their income. Statistical analysis shows that the differences were not significant.

Concerning the improved barley varieties adopters, the income of poor households increased by 3336SP in 2000/2001 and 10,250SP in 2001/2002. The income of sufficient households increased by 17,800SP per household in the first season and by 48,500SP per household in the second season. The upper intermediate households' income increased by 19,200SP per household in the second season. This increase in income may have transformed some households from lower living standard to a higher one, for example from poor to sufficient livelihood.

Table 8.12 **Contribution of improved barley varieties to increase in household income by living standard, Al Mahmoudly (SP/household)**

Living standard		2000/2001	2001/2002
Poor	Average	355	854
	SD	976	2959
Sufficient	Average	8895	24,258
	SD	21,640	53,944
Upper intermediate	Average	558	14,421
	SD	647	19,817
Average	Average	5122	15,364
	SD	16,518	41,636

Collected and elaborated from the survey

Effect of forage legumes on household income

The effect of forage legumes on household income was studied for only 2001/2002 season.

By community

There was little difference in increase in income between the two communities, which was about 930SP per household in Om Al Amad and 1200SP per household in Al Mahmoudly. This difference was mainly due to the difference in cultivated area under forage legumes, 198 donum under forage legume in Om Al Amad and 115 donum in Al Mahmoudly.

By adoption behavior

In both communities, forage legumes contributed to a noticeable increase in the income of adopting households. However, the non-adopting households were not affected by the technology (Table 8.13). The difference between adopters and not-adopters was significant at 1%.

Table 8.13 **Contribution of forage legumes technology to the increase in household income according to adoption behavior in both communities (SP/household)**

Community	Adoption	Average	SD
OM Al Amad	Non-adopters	10	62
	Adopters	3099	2064
Al Mahmoudly	Non-adopters	64	343
	Adopters	13,530	20,239

Collected and elaborated from the survey

By settlement zone

Al Mahmoudly community

Naturally, the biggest cultivated area under forage legume was in zone 2, it was less in zone 3 and disappeared in zone 4. The difference was reflected in the increase in household income in these zones (Table 8.14). However, the difference was not significant among the settlement zones.

Table 8.14 **Contribution of forage legumes to the increase in household income according to settlement zones, Al Mahmoudly community (SP/household)**

Zone	Average	SD
2	2706	9481
3	142	512
4	0	0

Collected and elaborated from the survey

By living standard of household

a. Om Al Amad community

The sufficient households benefited from the technology more than poor and very poor households, and even more than the upper intermediate households (Table 8.15). The sufficient households could afford the technology and they had no other activities through which they could increase their income. The poor households, however, could not afford the technology because of the high cost of the seed.

Table 8.15 **Contribution of forage legumes to increase in household income by living standard, Om Al Amad community (SP/household)**

Living standard	Average	SD
Very poor	491	1299
Poor	481	937
Sufficient	1157	2046
Upper intermediate	669	1337
Total average	931	1781

Collected and elaborated from the survey

b. Al Mahmoudly community

The benefit of this technology was not clearly noticed in the poor and upper intermediate households; but it was noticeable in the sufficient households (Table 8.16). However, statistical analysis showed no significant difference between their living standards.

Effect of early weaning

By community

This technology contributed more to the increase in household income in Om Al Amad than in Al Mahmoudly, because the number of adopters was more in Om Al Amad (Table 8.17). Statistical analysis showed no significant difference between the two communities.

Table 8.16 **Contribution of forage legumes to increase in household income by living standards, Al Mahmoudly community (SP/household)**

Livelihood standards	Average	S.D
Poor	0	0
Sufficient	2122	8214
Upper intermediate	0	0
Total average	1179	6145

Collected and elaborated from the survey

Table 8.17 **Contribution of early weaning to the increase in household income in both communities (SP/household)**

Community	Average	SD
Om Al Amad	1143	3427
Al Mahmoudly	625	2612
Average	947	3139

Collected and elaborated from the survey

By adoption behavior

The technology benefited only adopters in both communities, and the increase in income was almost equal (11,242SP/household). The difference between adopters and non-adopters was not significant.

By settlement zones

Al Mahmoudly community

Households that lived in zone 4 benefited most from the technology, followed by households in zone 2, while households in zone 3 did not benefit from it (Table 8.18).

Table 8.18 **Contribution of early weaning technology to increase in household income according to settlement zones in both communities (SP/households)**

Settlement zone	Average	S.D
2	749	2903
3	0	0
4	1405	3975
Total average	625	2612

By living standards

In both communities, only the sufficient households benefited from the technology, because no other household type applied it. The difference between their living standards was, however, not significant (Table 8.19).

Table 8.19 **Contribution of early weaning technology to increase in household income according to living standards in both communities (SP/households)**

	Living standards	Average	SD
Om Al Amad	Sufficient households	1775	4154
	All households	1143	3427
Al Mahmoudly	Sufficient households	1124	3460
	All households	625	2612

Collected and elaborated from the Survey

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9

Adoption and Impact Studies in Tunisia

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Introduction

Taking into consideration the problems of low rainfall areas and using a community participatory approach, the Tunisian Mashreq/Maghreb team developed a set of technologies that are well adapted to the Zoghmar community during the first phase of the project. The technologies were aimed to improve productivity and farmers' income, and to contribute to sustainability of natural resources. During the second phase of the project, the technologies were widely used by a large number of community members.

The introduction of new technologies often leads to some changes in the functioning of the production unit. These changes in turn have impact on the whole household-farm system. Therefore, monitoring and assessment of technology transfer should take into account the whole system and try to understand and integrate its working mechanisms. In this view and beyond the simple financial benefits of the technology, it is important to consider the impact of the technology on household (farm) income to explain the reasons for adoption or rejection of the technology. To achieve this, we conducted a research using systemic approach and monitoring of household accounts.

Methodology

Ex ante and *ex post* analyses and impact studies of technologies on the economic efficiency at the level of the plot were conducted and compared to a control (technologies used by the farmer). However, as mentioned above, the impact assessment of a given technology ought to be done at the level of the whole farm and based on the practices used by the farmer or herder. Moreover, it is necessary to analyze the agrarian system and its relationship with the environment. The community environment affects the adoption of some technologies.

Research on technology monitoring and adoption was done using several steps, including exhaustive households survey, sampling, typology, monitoring, result analysis, back to sampling, and back to population.

Exhaustive household survey
This survey covered all households in the community and focused on a limited number of pertinent parameters (agriculture area, age, livestock, equipment, etc). The objective of the survey was to generate a database on the community members and complete the results of the RRA implemented by the M&M team. Data was collected from various sources including Omdas, CTV (cellule territoriale de vulgarisation) chiefs and CRA (centre de rayonnement agricole) chiefs. Based on analysis of the data, a set of hypotheses related to farm functioning mechanisms and local agricultural economy were developed.

Sampling
Using data from the survey, a sample of beneficiary farmers, and others used as control, was selected to monitor the impact of the technology transfer. Sampling was done as follows:

Household survey
This was conducted using a questionnaire to obtain information on the household-farm system. Information was obtained on the following:

- family composition and history, labor, agricultural and off-farm activities of all household members and incomes;
- agricultural production system with its different components and its long-term evolution;
- results related to farm working mechanisms and their relationship with the environment;
- constraints and assets provided by the environment to the farm.

Typology
Data analysis, using multivariate analysis, helped in identifying the different types of household-farm systems and their composition.

Monitoring
Monitoring was done in farms where the M&M Project introduced improved technologies, and it focused on the following aspects:

- Technologies transferred
- Finances of the household-farm system
- Results of the technologies adopted

Data analysis
Data on the interaction between the traditional systems and promoted technologies were obtained from monitoring of farms. Several levels of analysis were done. A *priori* analysis enabled us to understand why some farmers refused to adopt the technology transfer process. On the other hand, and with collaborating farmers, it enabled us to identify the constraints faced during technology transfer and measure the adequacy of the technology within the production system.

Back to sampling
An analysis of the performance of target farms vis-à-vis the control enabled us to understand the impact of technology adoption.

Back to population
After identifying the factors that determined technology adoption, we then assessed the possibilities of technology transfer for the whole community.

In order to assess adoption levels by different farmer categories and to enable inter-regional comparison, clustering was done according to farm and flock size. The following types were identified:

- Clustering according to farm size
  Type 1: Total agricultural area (TAA) < 10ha
  Type 2: TAA 10–20ha
  Type 3: TAA > 20ha

- Clustering according to flock size
  Type 1: small size flock < 10 ewes
  Type 2: medium size flock, 10–30 ewes
  Type 3: large size flock > 30 ewes

Dominant speculations (crop or livestock) were also considered in the process of clustering or classification. Nevertheless, in the case of Zoghmar community this was not pertinent since most households practiced sheep production. Similarly, dominant land use types (private land holding, rented land, land in association or mixed) were not included since “direct exploitation mode” was the common practice. Besides, the project team intensively involved and closely monitored some farms within the community farms sample, while they monitored others, considered as the control group, less.

The preliminary results of technology transfer monitoring are presented in this report. It focuses on the main technologies introduced in Zoghmar community. These include manufacturing and use of feed blocks as supplement feed for sheep, introduction of improved rams, cactus, and improved vetch.

These and other technologies still in the process of evaluation (i.e., *Atriplex*) constitute coherent changes in cropping systems, allowing the shift from an extensive sheep production system towards a relatively more intensive system that is able to make better use of the natural resources and livestock of the community.

The report highlights some of the development problems in Zoghmar as well as the introduced technologies adopted by farmers. An economic evaluation based on partial budget implementation was used to evaluate introduced technologies. It helped in the determination of the advantage of introducing a new technology or upgrading an existing one.

Zoghmar Community

Zoghmar is an Imada of the Delegation of Jelma. It was created in 1991 and covers about 4300ha. The total population is 2400, with six different fractions, Hnazla, Rhama, Chouayhia, Anaybia, Baaounia and Mrazguia (Table 9.1).

Table 9.1 **Farms distribution by family and farm size (ha)**

Family group	Farms		Surface	
	Number	%	Hectare	%
1. Rhamna	28	7.1	300	7.0
2. Hnazla	120	30.3	1700	39.5
3. Chouayhia	170	42.9	1000	93.3
4. Mrazguia	25	6.3	500	11.6
5. Baaouina	40	10.1	500	11.6
6. Anaybia	13	3.3	300	7.0
Total	396	100	4300	100

Source: Imada of Zoghmar

Zoghmar zone consists of hills separated by valleys. Accessibility to the community is quite difficult during winter. The soils are rocky, there is severe deforestation and advanced soil erosion aggravated by frequent stormy rains. The annual rainfall (monitored at Jelma station located 13km from the community) averages 270mm with inter- and intra-annual variability. The average rainfall is 94.3mm, 59.4mm, 87.8mm and 27.2mm for autumn, winter, spring and summer respectively. Dominant winds are from east and west and sirocco happens during summer and autumn, which last 40–70 days per year and dry up all green vegetation.

Moreover, Zoghmar community experienced continuous drought for four years, therefore, only 50mm of rainfall was recorded from September to March during 2000–2001 cropping season, following a 1999–2000 dry year. Because of this drought, rainfed crops failed completely, so only irrigated crops were monitored.

Sheep herding is the main economic activity of the zone. Cereal cropping (barley and wheat) and tree planting (olive trees mainly) are the main cropping activities. Yields are quite low, about 200–300kg per hectare for cereals.

Most farmers leave within the community, and houses are grouped by family. The houses are made of stone and have 2–3 rooms each. Power supply reached the community in 1997 and all houses are currently electrified. Pipe-borne water is available at about 8TD per cistern of 5000 liter. The community also has two primary schools and one health center.

The main constraint to development of the agricultural sector is limited availability of water. The main activity was the creation of an irrigated perimeter, with very few beneficiaries. The irrigated perimeter covers 120ha distributed among 52 farms belonging to three groups, namely, Anaybia, Baaouina and Chouayhia. Water is obtained from a borehole that was constructed in 1995, which flows at 45 liter/second and is of good quality (0.6g/l). Cereals, fodder and vegetables are the main irrigated crops. Moreover, 33 farmers obtained credit to develop dairy cattle.

The irrigated perimeter is a dynamic technology in the community that has potentials to transform the current production system of the whole zone. It has resulted in the introduction of new technologies such as the development of irrigated fodder crops (oats) for hay-making and/or green fodder use.

Farms typology in Zoghmar

Based on the survey conducted on 40 households, subject to the monitoring of technology transfer, a production systems typology was developed. It highlights the importance of livestock and multiple activities in the development of the farm. It was developed to place the introduced technology within the whole system in order to assess its compatibility and likely adaptation.

Principal components of analysis associated with ascendant hierarchical classification enabled us to distinguish four groups, namely, pastoralists, agro-pastoralists, medium-size herders and active crop producers.

Group 1: Pastoralists

This group comprised six farmers, representing 15% of the total sample. They were referred to as pastoralists because of their large flock size compared to the total cropping area. The average number of sheep was 95 and average cropping area was 29.5ha, making 3.8 sheep per hectare, which is extremely high.

Farmers in this group grew barley on about 86% of their total agricultural area (TAA) and had about 5ha of cactus. Tree planting is quite recent and the average olive plantation age was 3.5 years. The group performed better economically, with off-farm income of only 13% of total income.

Table 9.2 **Characteristics of pastoralists**

	Mean	Standard deviation	Coefficient of variation
Total agricultural area (ha)	29.50	6.80	0.23
Number of sheep	95.00	35.93	0.37
% of cereals in TAA	85.83	17.70	0.20
Age of olive trees plantation	3.50	3.81	1.09
Agricultural income (TD/year)	7124.00	3227.00	0.45
Off-farm income (%)	13.33	7.86	0.59

Group 2: Agro-pastoralists

This group comprised 13 farmers, representing 32.5% of the total sample. The imbalance between livestock and agricultural area was less pronounced in the group and the average age of olive plantations was higher. Average flock size was 51, with an average total agricultural area of 36.07ha, corresponding to a carrying capacity of 1.77 sheep per hectare. Cropping area represented 81% of the total agricultural area, used mainly for cereals (50.3%), barley (55%) and 45% wheat). The average age of olive plantations (21 years) shows the traditional importance of the crop. Agricultural income was higher than the total sample average, while off-farm income represented 20% of total income. Moreover, this group had a higher acreage of cactus; 7ha per farm.

Table 9.3 **Characteristics of agro-pastoralists**

	Mean	Standard deviation	Coefficient of variation
Total agricultural area (ha)	36.07	29.44	0.81
Number of sheep	51.46	40.22	0.78
% of cereals in TAA	50.30	13.43	0.26
Age of olive trees plantation	21.23	11.77	0.55
Agricultural income (TD/year)	3495.76	2513.42	0.71
Off-farm income (%)	20.38	40.71	1.99

Group 3: Medium size herders

There were 11 farmers in this group (27.5% of total sample), with an average of 38 sheep and total agricultural area of 13ha. Thus, the average carrying capacity per hectare was 3.2 sheep. The agricultural area was cropped mainly (83%) with cereals (50% barley, 50% wheat). The production system of this group is evolving with the recent introduction of olive trees. The economic performance of the group was poor, while off-farm income was about 10% of the total income.

Table 9.4 **Characteristics of medium size herders**

	Mean	Standard deviation	Coefficient of variation
Total agricultural area (ha)	13.00	7.07	0.54
Number of sheep	37.72	23.19	0.61
% of cereals in TAA	83.27	13.94	0.16
Age of olive trees plantation	3.81	3.80	0.99
Agricultural income (TD/year)	1407.00	854.86	0.60
Off-farm income (%)	10.09	11.79	1.16

Group 4: Farmers with multiple activities

This group comprised 10 farmers (25% of total sample), having an average 15 sheep on 16.7ha, giving a carrying capacity of 1.2 sheep per hectare. Cropping area was 75% of total agricultural area, used mainly (82%) for cereals (40% barley and 60% wheat) production. The group's income from agriculture was the lowest but off-farm income was high (69% of total income). Farmers in this group had an average of 1.45ha of cactus only.

Table 9.5 **Characteristics of farmers with multiple activities**

	Mean	Standard deviation	Coefficient of variation
Total agricultural area (ha)	16.70	4.40	0.26
Number of sheep	14.90	7.17	0.48
% of cereals TAA	81.90	10.56	0.12
Age of olive trees plantation	8.60	6.81	0.79
Agricultural income (TD/year)	810.00	566.01	0.69
Off-farm income (%)	69.10	17.38	0.25

This typology highlights the diversity of farmers in Zoghmar community. It also shows the impact of the nomadic and pastoral background as well as recent changes on the zone. Sheep were an important component of the production systems. Olive trees were another component because of government policy on agricultural development and modernization. Nevertheless, and in view of the unfavorable conditions for agricultural development, a large part of the income of the population was from off-farm activities. This typology will help us to understand the technology adoption process.

Technology 1: Feed Blocks

Background: Livestock sector in Zoghmar

The majority of farmers in Zoghmar include cereal straw in livestock diets, but the quantity of straw fed to sheep varies among farmers. Some farmers use straw as the basal diet while others use small amounts of it. Almost two thirds of farmers use spiny cactus, which has high soluble carbohydrates and water, and thus may alleviate energy deficiency and water scarcity mainly during drought seasons. They however do not feed cactus to animals during cold seasons because of the belief that cactus consumption during these periods will reduce body temperature in animals and may cause health problems. We also noted that only 40% of farmers allowed their animals to graze in the pasture. In Zoghmar, pastures are degraded and thus cannot provide sufficient nutrients to animals. There were significant fluctuations in the prices of feed depending on their source and the period. For example, the cost of one bale of straw increased from 1.7TD in summer to 2.7TD in spring 2000.

Table 9.6 **Characteristics of farms in Zoghmar**

Farmers	Area (ha)	Roughages (ha)	Rangeland (ha)	Spineless cactus	Cereals (ha)	Ewes (ha)
Saasougui Belgacem	53	0	0	0	33	100
Chihaoui Amara	50	0	0	0	40	90
Med Ben Abdrrahman	40	0	6	6	10	80
Khaled ben Amor	18	0	1	1	15	70
Zliti Med Béchir	6	-	-	-	-	-
Abdesslam Ben Med	15	0	0	0	6	15
Hanzouli Ahmed	12	0	0	0	3	15
Zliti Naceur	3	0	0	0	2	5
Med Ben Saad	20	3	0	0	0	2

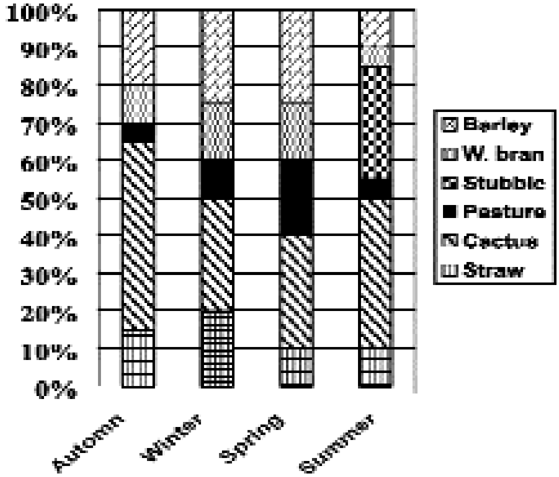

Figure 9.1 **Approximate composition of diets given to sheep in Zoghmar**

Figure 9.1 shows the annual feeding calendar adopted in Zoghmar. Feed shortage is the main constraint to sheep production. Thus, pressure on natural resources is increasing and, when associated with frequent droughts, has led to increased use of supplement feeds. The main objective of using feed blocks is to reduce feed costs and pressure on natural rangelands.

Technology objectives

Aims of the feed block technology

- To reduce the use of common concentrate feeds and feeding cost.

- To provide small holders with a stock of feed supplements that can be managed in any condition during the year.
- To provide livestock fed on poor quality roughages with a balanced supply of main nutrients (energy, nitrogen and minerals).
- To offer farmers a simple and cost-effective technique for preserving several by-products — high moisture content by-products such as olive cake and tomato pulp, and several other by-products (wheat bran, wheat flour residues, etc).

Description of the technology

Feed block is a solidified mixture of several agro-industrial by-products for supplementing small ruminant feed. It is considered as a catalyst supplement allowing fractionated, synchronized, and balanced supply of the main nutrients (i.e., energy, nitrogen, minerals and vitamins) for animals. The greatest value of feed blocks lies in their role as cost-effective supplements and as a means for preserving several high moisture agro-industrial by-products (e.g., tomato pulp, olive cake, etc).

Feed block technology is simple and does not require sophisticated equipment. Small farmers can manufacture and handle feed blocks, a process that has been mechanized in Iraq, where large quantities are continuously being made and distributed to farmers. A wide range of feed block formulas may be used depending on availability of ingredients. In Iraq, date pulp, rice bran and poultry waste are the main ingredients used in making feed blocks. However, olive cake and tomato pulp-based feed blocks are widely used in Tunisia. Molasses, and brewer grain and molasses are the main ingredients used for making feed blocks in Morocco and Jordan respectively.

Feed block technology may play an important role in livestock production in WANA. This alternative supplement improves the nutritive value of low quality diets, and thus animal performance; and it reduces livestock feeding costs. Feed blocks may reduce the need for conventional concentrate feeds (barley grains, commercial concentrate, etc) by more than 50%, thus reducing imports considerably particularly in dry years. In Tunisia, a ton of feed blocks costs about US$95, compared to US$200 for a ton of barley.

Highlights on relevant trials

On-station and on-farm trials were conducted to inform farmers about the benefits of using feed block technology. Two types of feed blocks were tested at the laboratory level, validated on experimental station flocks and evaluated at the farmer level. In the following section we will describe a trial on replacing farmer concentrate (2/3 barley grain + 1/3 wheat bran) with feed blocks and the effect on sheep performance and feeding costs.

Olive cake and tomato pulp are the most abundant by-products in the target area. Therefore, feed blocks based on olive cake or tomato pulp were evaluated on yearling lambs. The following diets were tested:

D1: straw *ad libitum* + 500g concentrate
D2: straw *ad libitum* + 250g concentrate + tomato pulp feed blocks
D3: straw *ad libitum* + 250g concentrate + olive cake feed blocks

D4: straw *ad libitum* + 125g concentrate + tomato pulp feed blocks
D5: straw *ad libitum* + 125g concentrate + olive cake feed blocks

The results show that it is possible to reduce the proportion of farmer concentrate in the diet of sheep. Feed blocks seem to be a useful supplement. However, animals fed on olive cake-based feed blocks performed better than those fed on tomato pulp-based feed blocks. Additionally, olive cake, in contrast to tomato pulp-based feed blocks, reduced the feeding cost of animals. This phenomenon may be attributed to the feed block composition. Indeed, olive cake feed blocks contain rapeseed meal, which provides the animal with proteins and urea, two sources of nitrogen that are not included in tomato pulp feed blocks for several reasons. Our initial assumption when formulating feed blocks was that tomato pulp contains more crude protein than olive cake (20% vs. 5% of dry matter). We therefore preferred not to include urea in tomato pulp-based feed blocks from a nutrition point of view as well as to avoid any risk of misuse that could cause animal intoxication. However, results obtained in this study call for a revision of the formula for tomato pulp feed blocks.

Evaluation
Table 7 presents data on feeding costs. It is worth noting that olive cake-based feed blocks may reduce the cost of 100g daily weight gain by about 20%. In addition, the use of this type of feed blocks may reduce the proportion of farmer concentrate by 75% without negatively affecting sheep performance.

The increased feeding cost, with the use of tomato pulp-based feed blocks, should however not be considered as a negative result. Indeed, this trend may fit with several farmer objectives. In some situations, farmers may be interested in having a supplement feed bank that could be used to maintain livestock flocks during severe drought seasons.

Using these data, we were able (i) to assess the level and degree of technology adoption for the different farm types (ii) by using national statistics to assess the expected financial impact through a larger diffusion of the technology.

Table 9.7 **Estimation of diet costs (millimes)**

Diets	**D1**	**D2**	**D3**	**D4**	**D5**
Minimum diet cost	127	131	131	109	117
Minimum cost for 100g daily gain 201	229	178	224	177	
Variation in feeding cost (% of control diet D1)	-	+19.8	-10.8	+17.9	-11.2

From the analysis, it appears that we were at the level of adoption for the target zone. Adoption levels during 2000–2001 cropping season were extremely low (13% of monitored farms sample), considering the performance of the technology and its wide adoption at the national level. The cost of manufactured blocks at the community level was high, because of the lack of mechanization and the required high labor cost. The other important constraint was poor organization of the community, making the purchase of input for feed blocks rather difficult.

The adoption rate calculated for the different farm types was high (54.4%) for participating farmers (those who were closely monitored by the research team). This is consistent with the project approach, which relied on participating farmers to spread the technology to other farmers.

Taking into consideration the farms typology, our findings show a high and significant correlation between flock size and level of use, incorporating feed blocks into the feed calendar. Therefore, mainly farmers having flock sizes higher than 30 ewes adopted feed blocks.

A financial analysis of data on feed blocks use at the national level was provided, which allowed us to implement a financial analysis on a wider scale. Thus, during 1999–2000 cropping season, even though adoption at the project zone was low, adoption rate at the national level was up to 5.17%. This level increased progressively to reach 9.36% in 2001–2002. The adoption of this technology will help save about 90 million TD per year. The use of feed blocks to replace some of the conventional concentrate feeds led to an internal net return (IRR) of 57–58% for 10–15 years.

These results confirm the potential value of feed block technology in the project area and at the national level.

In conclusion, despite the good performance of feed block technology (significant reduction of purchased concentrate feeds and maintenance and even improvement of sheep performances), the main constraint remains the development of semi-mechanized feed block manufacturing at the community level. This constraint could be alleviated through the provision of small feed block manufacturing units to farmer leaders and/or local community institutions (AIC).

Technology 2: Introduction of Improved Rams

Background and objective

In Zoghmar, farmers use their own rams for breeding purposes in the same flock for many years. There is no tradition of exchanging rams for breeding, a practice that has led to a high rate of inbreeding and low growth rate of lambs. Therefore, improved rams was introduced to increase the productivity of the flocks by reducing inbreeding and improving growth performance.

Description and highlights

- Introduction of improved rams selected by the Livestock and Pasture Office (OEP) breeding team, based on their growth performance.
- Farmers bought rams from OEP.
- Farmers who were beneficiaries of rangeland management subsidies paid only the difference between the ram price and the equivalent of subsidies.
- Recording growth performances.
- Data analysis of lambs' growth according to their pedigree.
- Comparison of results of growth of lambs intra-flock in order to show the contribution of improved rams on the growth of lambs.

Financial and economic evaluation

Introduction of improved rams increased average daily weight gains from 1 to 4.5kg in 90 days. If we assume that the feeding cost of 1kg live weight gain is about 1.3TD, and the average price of 1kg live weight is 3.5TD, the results in Table 9.8 would be obtained. The weight gain per lamb may reach 10TD, corresponding to 10–15% of the lamb value at three months. In addition to this benefit, herders favorably accepted improved rams, which is indicated by the increase in number of farmers who were willing to use them.

Table 9.8 **Effect of improved rams on lamb growth**

	Herder 1	Herder 2	Herder 3	Herder 4
Number of ewes	92.0	27.0	79.0	82.0
Prolificacy (%)	145.0	125.0	124.0	115.0
Live weight at 90 days (1999/2000) (kg)	19.0	15.5	16.0	13.0
Live weight at 90 days (2000/2001) (kg)	20.0	17.3	18.4	17.5
Weight gain (kg)	1.0	1.8	2.4	4.5
Additional charges (TD)	1.3	2.3	3.1	5.9
Additional products (TD)	3.5	6.3	8.4	15.8
Net effect of improved rams per lamb (TD)	2.2	4.0	5.3	9.9

The adoption process

Results obtained show high level adoption of the technology by farmers in Zoghmar. The average adoption rate was 20.5% for the studied sample, with adoption levels (degree of adoption) of 17.34 and 17.6 for total agricultural area and livestock respectively. In addition, these indicators were related to farm characteristics (typology), and the highest values for adoption rate and degree of adoption were obtained with large farms. Similar results were observed with farms having large size flocks.

The effect of the project was again visible in the support that the introduction of improved rams received from the use of other technologies, e.g., cactus planting. The livestock and pasture authority provides subsidies for cactus planting on private lands, an incentive that is given to cover the purchase of an improved ram totally or partially. It is worth mentioning that the introduction of improved rams was part of a wider effort on livestock improvement. It was associated with activities related to sheep feeding management, promotion of alternative feed sources, increasing on-farm fodder production and prolificacy. Therefore, an analysis of the broad package of these techniques was necessary.

Technology 3: Cactus

Background

The establishment of a sustainable production system is a mandatory task for agriculturally marginalized areas. Cactus is a drought-tolerant fodder species suitable for food security in rural high population zones, livestock feed resources, biodiversity conservation and increase in farmers' income. Its increased importance in arid zones, characterized by harsh climatic conditions (low and irregular rainfall), poor soils and degraded natural resources, results from its ability to withstand harsh conditions and prolonged drought periods while producing sufficient forage fruits and other useful products. Moreover, once established, cactus reduces wind and soil erosion.

For years, spineless cactus was grown on a large scale in arid and semi-arid zones, and nowadays, about 500,000 hectares are planted. Cactus is encountered in areas where most other plant species fail to grow (areas of 150–400mm average rainfall) because of its phenological and physiological structures. Its production reaches between 20 and 100 tons per year.

Objectives

Natural rangelands in West Asia and North Africa are subjected to continuous grazing. Native or introduced vegetation biomass is low and dominated by unpalatable noxious species. Moreover, the soil of marginal cereal cropping lands is bare and the top soil eroded by wind. Only non-palatable plant species prevail. To restore good vegetative cover for the rangelands or marginal cereal lands, therefore, improvement techniques should be implemented to meet the following objectives:

- Improvement of rangelands productivity
- Increase in marginal cereal cropping lands productivity
- Integrating cactus as an alternative feed resource into the feed calendar
- Improving farmers' income

Highlights of relevant trials

The introduction of spineless cactus and fodder shrubs was aimed to rehabilitate rangelands and marginal cereal cropping lands. Cactus was therefore established and combined with the introduction of herbaceous forage and pasture species in an alley cropping pattern to increase the productivity of cereal cropping lands.

Several techniques were implemented according to the cropping system, farm size and agro-ecological characteristics of the target area.

Cactus was introduced with densities varying from 800 to 8000 double pads per hectare and rows and row intervals were assigned based on the main purpose of establishing the cactus (natural rangelands or marginal cereal lands). Several techniques of planting shrubs and cacti were also used, depending on the land tenure system:

- On communal rangelands, introduced species were planted in rows without removing the natural herbaceous or woody natural species.
- On private lands, alley cropping technique was preferred so that farmers could crop the area between rows when rainfall conditions were favorable.
- On both types of land tenure, when water and soil conservation techniques were applied, shrubs and cactus were planted according to the contour lines in order to consolidate (reinforce) the so-called *tabias*.

Another type is related to cactus and is obviously the oldest one, that is, the *bosquet* type, which is a very dense plantation surrounding the house and used for fruit cropping and fodder supplement for animals indoors.

Adoption process

The participatory approach was used in implementing cactus on private rangelands in Tunisia.

1. *Farmers' contribution*
- Plowing the soil
- Planting pads
- Maintaining planted areas for three years

2. *Government's contribution*
- Providing cactus pads
- Providing subsidies to support part of the farmers' expenses on to soil preparation and planting
- Providing compensation (replacement of lost output as a result of no grazing) per hectare, per year for three years); and feed concentrates and/other feed resources and technologies (feed blocks, improved rams, straw treatment with urea, forage seeds).

Results of the adoption process

As in other technologies, adoption rates and degree of adoption were calculated for cactus planting as an alternative fodder source and as a tool for rangeland improvement for all farms, and for participating farms (samples monitored). Both farm types reacted favorably to this technology and high adoption rates were recorded (46.2%), with high degree of adoption (50.4%) reported for rangeland and fallow land areas that could be planted with cactus. In addition, the surface planted with cactus increased with farm size, reflecting the capability of farmers to release a part of their land for cactus cropping.

Surprisingly, however, there was no relationship between the area planted with cactus and livestock numbers for small-size and medium-size herders. Livestock small holders seemed to have planted relatively more cactus than medium-size herders. The average cactus crop area was 6.1 and 6.8ha for medium size and small size flock owners respectively, while large flock owners had an average of 13.9ha of cactus.

These findings reflect the various strategies adopted by different farmer categories. Some planted cactus to cover their own fodder, others planted it to sell pads, and some others just to benefit from incentives provided by OEP.

In relation to the dominant cropping system, we noticed cactus was also well adopted by crop producers. This can be explained by the fact that cactus is a multipurpose crop. It helps to control erosion, rehabilitate degraded rangelands, and can be used as a cash crop (fruits and pads). For Zoghmar, cactus helped to reduce fallow lands and degraded rangelands by about 50%.

Financial and economic evaluation
As in other technologies, partial budget method was used for this evaluation. Cactus was planted to improve marginal rangelands, or on marginal cereal lands. In both cases, it was planted by individual farmers or with support from OEP. Therefore, economic evaluation considered both cases (with and without OEP support) and assumed that a cactus plantation lasts 15 years averagely, but the duration is usually higher (20 years and more). For each scenario, the partial budget was calculated to understand and/or anticipate farmers' decision.

Moreover, climatic variation expressed in terms of drought occurrence was considered for cactus, rangeland, and wheat cropping (alley copping and full crop). Average figures of 40%, 30% and 30% were used as frequency for medium, dry and good years respectively. As a hypothesis, we assumed that only cactus pads were to be marketed; fruits were not considered even if they were consumed by farmer households.

An additional factor included in the calculation was the support of agricultural authorities, estimated to be up to 10TD/technician/ha/year during the first four years of crop establishment. Results of these different scenarios are presented in the next sub-sections.

Cactus on natural rangelands
Cactus planting on marginal lands was highly profitable. The annual balance was always positive and pushed farmers to go for this highly subsidized crop by government (OEP). The calculated actual net value (ANV) was high for arid areas and rangelands. Besides, financial results were positive for all the period under consideration, which will help in adoption and diffusion of the technology.

Table 9.9 **Evaluation of cactus plantations on natural rangelands with subsidies**

Products	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6 to 15**	**VAN**	**TRI**
Natural rangelands	17	17	17	17.0	17.0	17		
Cactus with OEP	33	95	120	201.6	268.8	336		
Balance	16	78	103	184.6	251.8	319	1655.90	Values 0
Cost of R-D considered	6	68	93	174.6	251.8	319	1624.90	Idem

Table 9.10 **Evaluation of cactus plantations on natural rangelands without subsidies**

Products	**Y1**	**Y2**	**Y3**	**Y4**	**Y5**	**Y6 to 15**	**VAN**	**IRR (%)**
Natural rangelands	17	17	17	17.0	17.0	17		
Cactus with OEP	-112	50	75	201.6	268.8	336		
Balance	-129	33	58	184.6	251.8	319	1453.09	80
Cost of R-D considered	-139	23	48	174.6	251.8	319	1421.39	73

Even if subsidies allocated by OEP were not included, calculations show clearly that cactus cropping was profitable. The average profit compared to the reference (marginal land) was about 120TD per hectare. The high values obtained for net returns showed economic advantage of cactus cropping, even when fruit production and erosion control (soil and vegetation restoration) were not included in the calculations. Their economic value was probably higher than expected.

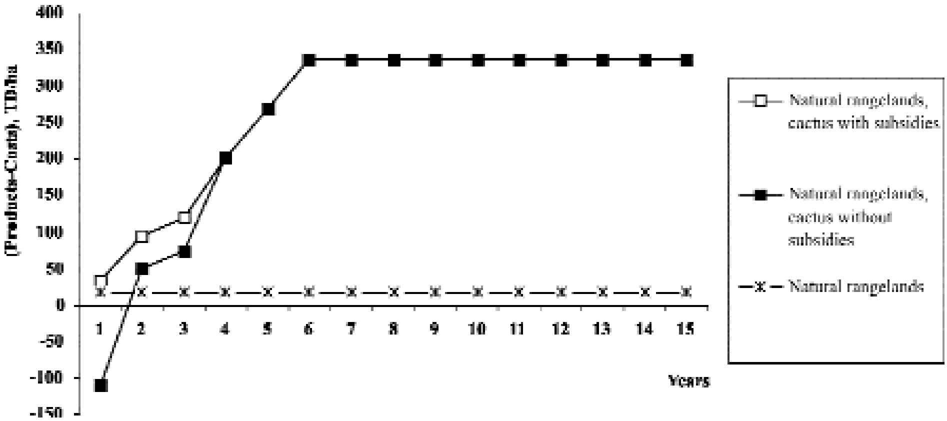

Figure 12.2

Cactus on marginal cereal lands

Cactus may be planted alone without cropping the area between rows. In this case, except in the first year (year of planting) with or without OEP intervention, cactus provided profits reaching 336TD after the fifth year or an average of 150TD per hectare per year, which is equivalent to 1000kg of barley.

Where the area between rows was copped with cereals (75% of the area planted to cactus), the profit per hectare increased by 12% compared to the earlier case.

Table 9.11 **Evaluation of cactus plantations on marginal lands with subsidies**

Products	Y1	Y2	Y3	Y4	Y5	Y6 to 15	VAN	TRI
Marginal cereal lands	46	46	46	46	46			
Cactus with OEP	33	95	120	280	310	336		
Balance	-13	49	74	234	264	290	1514.46	453
Cost of R-D considered	-23	39	64	224	264	290	1482.76	258
Cactus without OEP	-112	50	75	280	310	336		
Balance	-158	4	29	234	264	290	1311.64	66
Cost of R-D considered	-168	-6	19	224	264	290	1279.94	61

Table 9.12 **Evaluation of cactus plantations on marginal lands without subsidies**

Products	Y1	Y2	Y3	Y4	Y5	Y6 to 15	VAN	TRI
Marginal cereal lands	46	46	46	46	46	46		
Cactus with OEP and cereals	66	128	153	300	369	369		
Balance	20	82	107	254	294	323	1754.72	Values ≤ 0
Cost of R-D considered	10	72	97	244	294	323	1723.02	Values ≤ 0
Cactus without OEP and cereals	-79	83	108	300	340	369		
Balance	-125	37	62	254	294	323	1551.90	89 %
Cost of R-D considered	-135	27	52	244	294	323	1520.20	81 %

Cactus is a profitable crop for arid and semi-arid environments. It is profitable because of its various products and its low establishment and maintenance costs, and because of other available alternatives (alley cropping). Cactus planting allows farmers to crop cereals on marginal lands and helps in controling erosion especially on slopy lands.

Perspectives

Once established on either natural rangelands or marginal cereal cropping lands, cactus is considered for its endurance and sustainability. The productivity of areas that were previously used for continuous grazing or cereal cropping needs to be properly managed. Therefore, a proper grazing program should be assigned for such areas in an integrated scheme, to alleviate livestock pressure and provide valuable feed resources to alleviate feed shortage.

Results of economical and financial evaluation as well as indicators of adoption show the favorable response of farmers to this technology. The landscape of the whole community and surrounding regions is changing, green cactus spots are increasingly and favorably invading spaces that used to be dry and eroded.

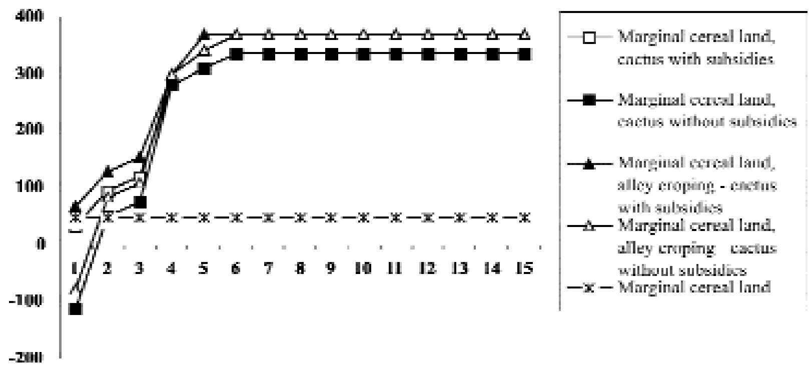

Figure 12.3

Technology 4: Improved Varieties of Vetch and Accompanying Technology Package

Background

Land use in Zoghmar, as typical of arid and semi-arid zones in Tunisia, is characterized by erratic cereal cropping and fallow, covering about 85% of total agricultural lands. Cereal cropping is usually developed at the expense of forage crops and rangelands. This situation has created a large gap between livestock requirements and locally available feed resources. To provide livestock needs, farmers graze fallow lands and meager rangelands, use some by-products, and purchase supplement feeds. In order to contribute towards solving this problem, we tested alternative solutions with community members, based mainly on introduction of improved varieties.

Objectives

1. To introduce improved varieties that will replace local varieties and improve fodder production.
2. To introduce fodder in the rotation, with the aim of:
   - increasing production at the farm level;
   - improving soil quality and especially nitrogen content;
   - inducing among farmers the habit of fodder production.

Description of the technology

Improved barley and oat were introduced to replace their corresponding local varieties, while vetch was introduced to replace fallow. The technologies transferred made use of rainfed as well as irrigated farms. Vetch was exclusively for rainfed plots within a framework of biannual rotation vetch/barley, while oat was on irrigated area only, and barley was used for both irrigated and rainfed agriculture. The several valorization options are discussed.

Barley

Barley is a rainfed crop used mainly for grain and straw production, but when there is insufficient rainfall, it is grazed. Irrigated barley is used as green fodder (grazed and/or cut and carry) during winter. As from February, the crop is kept for grain and straw production.

Vetch

Under completely rainfed conditions, vetch is grazed early in the season (December), when it is 20–25cm tall, but later the plant is left for hay and grain production.

Oat

Oat is dedicated for irrigated areas only, and it is used for hay production. Nevertheless, the crop is used as green fodder in some cases when it is 25cm tall, prior to hay production.

Highlights of relevant trials

Transfer of technology was implemented in farmers' fields to enable them to take decision on the varieties of fodder and cereals introduced, on fallow land, and the appropriate use of the different species.

The aim of the technology was to convince farmers on the need to diversify their crops in order to make better use of production factors (soil, fertilizer, water, etc), and to reduce emphasis on fallow land, which is still occupying 40% of total agricultural land.

The introduction of fodder crops will improve traditional rotation (cereal/fallow) and provide livestock requirements by enhancing integration and productivity.

Compared to traditional crops, improved varieties with improved technology packages will significantly improve yields.

Table 9.13 **Impact of new varieties and technological package on yields**

	Fodder yield (tons)	Grain yield (tons)	Straw yield (bales)
Farmer's plot (control)	2.2	0.25	120
Experimental plot	4.5	0.55	88

Adoption process

Technology adoption can take place through several processes.

1. Direct contact between farmers and scientists, in which case a targeted topic is discussed (sowing, fertilizer application, harvesting, etc) during each visit, depending on the period of the season.
2. Selection of experimental plot, an important process through which priority is given to leading farmers who can spread the technique to other farmers.
3. Results evaluation — During harvesting, demonstration days are organized to allow participant farmers and other community members to estimate the benefits of introduced technologies in comparison with the control.

Results of the Adoption Process

The work on crops covered several species/varieties, including barley, oat and vetch. However, we agreed to present results on only vetch for Tunisia, but the impact of all new varieties and accompanying technical packages was analyzed. The results are summarized in Table 9.14. It shows that adoption of vetch in the copping system was low, with average adoption rate of only 10.3%. Considering the different farm types, it appears that participating farmers mainly adhered to their own technology, and the process of diffusion was at its early stage. The highest rates of adoption were reported among large size farm owners, because of they could afford to establish vetch crop during the first year. This is an important finding, because vetch was introduced to replace fallow practice, which does not require funds.

Financial and economic evaluation

The results of partial budgets calculation for technologies related to introduction of vetch (versus fallow) are presented in Table 9.14.

Vetch produced a higher profit (+185TD per hectare) compared to fallow, which explains the high demand for the crop by farmers. However, additional benefits of vetch such as improvement of fodder balance, easy management, etc, were not included in this calculation. The only constraint is the limited availability of seeds.

Table 9.14 **Comparison of partial budget between vetch rainfed (B) and fallow (A)**

In favor (B compared to A)	Against (B compared to A)
Additional product of B = 420TD	Less product of A = 10TD
Less charges of A = 0TD	Additional charges of B = 215TD
Total = 420TD	Total = 225TD
Potential income variation (TD/ha) = 420 - 225 = +195 TD	

A major constraint to the diffusion and adoption of a new technology in arid environments is the climate (drought). During project implementation, the area experienced successive drought and vetch productivity fluctuated especially at the beginning of crop introduction. Vetch increases soil moisture reserve, but this was not monitored and, subsequently, was not included in the calculation.

To account for climatic variation, three types of years were considered: good, medium and dry years, with frequencies of 0.3, 0.4 and 0.3 respectively. Weighted values were thus calculated for economic indicators (IRR, VAN, etc), which were more realistic than values based on a single year.

Data were collected for each farm on all product types (hay, pasture, green fodder). When the product have been used by livestock, the biomass was converted to average daily gains and then to meat production and its market value. Results of these calculations are presented in Table 12.15.

Table 9.15 **Cost, value and benefits of vetch**

Farmer	Total cost	Total value	Benefits
1	162	689.72	527.72
2	194	891.07	697.07
3	216	795.72	579.72
4	116	785.40	669.40
5	156	655.45	499.45
6	120	461.24	341.24
Average	160.7	713.10	552.44

Average yearly benefit was about 552TD per hectare. To account for climate risk, costs and production were calculated for different year types and the results are summarized in Table 9.16. The data were than used to calculate economic and financial indicators of vetch technology adoption by farmers of Zoghmar community.

Despite variations in the climate and occurrence of drought, which affected crop production heavily, good results were obtained, and it seemed to be attractive to farmers, who were willing to adopt the variety and its accompanying technological package.

Table 9.16 **Costs, products and benefit per year type**

	Occurrence (probability)	Costs	Products	Benefits
Good year	0.3	180.67	891.38	710.71
Medium year	0.4	160.67	713.10	552.44
Dry year	0.3	93.67	-93.67	-93.67
Weighed values	1	146.57	552.65	406.69

Table 9.17 **Long-term economic indicators of vetch crop**

	Y1	Y2	Y3 to 10	VAN	IRR
Cost	146.57	146.57	146.57		
Product	0.00	552.65	552.65		
Net benefits of fallow	10.00	10.00	10.00		
Net benefits of vetch	-146.57	406.69	406.69		
Net benefits	-156.57	396.09	396.09	1931.37	253 %

Prospects

The success of this type of intervention requires large-scale implementation in experimental plots so as to extend it to the whole village or community. About 40 farmers in Zoghmar participated in the project in 2001-2002 season. There is a need for extension departments of the Ministry of Agriculture to be more involved so that they can take over the technology. This will also enhance its transfer to other users in similar zones. There is also a need to ensure that seed of improved varieties are made available to farmers.

Conclusion

Economic evaluation of the technologies transferred to Zoghmar community gave encouraging results, capable of boosting their diffusion and adoption. However, adoption rates were low for feed blocks and vetch. This may be attributed to the lack of inputs, such as vetch seeds and mechanized manufacturing units for feed blocks, for a larger diffusion.

In contrast, cactus and, to a lesser extent, improved rams technologies, presented the potentials of being adapted in the project communities. Farmers responded well to these technologies because they fit into the current production systems, in addition to the other favorable conditions such as the incentives provided by OEP. Moreover, the two technologies are closely linked and target improvement in sheep production, which is the main concern of the project communities. The technologies have potentials to significantly increase productivity, improve the environment and farmers' income.

These findings will significantly enhance efforts in promoting adoption in other communities.