Chapter 6: Economic evaluation and adoption of improved technologies

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6.1 Economic evaluation of improved technologies

6.1.1 Introduction

Nowadays, many agricultural researchers incorporate some level of economic analysis in their decisions concerning which alternative technologies or practices to recommend to farmers to improve their incomes. This is in contrast to the previous two decades, when little or no economic criteria were included in the decision-making process. At that time, research recommendations were based only on yield increases. Those recommendations were biased by supposing that this is the only factor farmers consider when making decisions. However, it is clear that other criteria such as costs, returns and risks may impact profitability, and therefore must be taken into account in the early stages of research planning and analysis. In reality, farmers often manage a very complex system of enterprises that may include various crops, animal production and off-farm activities. However, they are interested in the economic performance of the technology. In fact, they attempt to evaluate the net benefits of different interventions and usually take risk into account. They may prefer stable returns to the highest one when risk criteria are considered. To achieve a higher rate of adoption for a new technology, researchers must be aware of the social and economic elements of farming, as well as the biological ones.

In this study, an economic evaluation of water-use efficiency technologies proposed and tested by the agronomic team in the Tadla Irrigated Perimeter was carried out. To capture climatic variability, the analysis was conducted during two contrasting years (dry and wet). Total annual rainfall was 357 mm in 2005/06 (wet year) and 296 mm in 2006/07 (dry year). During the first year, precipitation was well distributed throughout the season. However, the second year was wet at the beginning, dry in the middle and very wet at the end of the season.

6.1.2 Methodology

A field experiment and evaluation was carried out with the two Benchmark communities during three cropping seasons (2005/06, 2006/07 and 2007/08). The five technologies evaluated in this chapter are well described in the biophysical reports (see Chapter 4). The proposed water-use efficiency technologies in this study were:

- Optimal rate of nitrogen. This fertilizer trial consisted of three rates of nitrogen (60 kg N/ha, 120 kg N/ha and 180 kg N/ha) and the farmers' usual practice.
- Improved surface irrigation. Three treatments were compared: 1) farmers' usual irrigation and crop management (Farmer); 2) improved surface irrigation with farmers' usual crop management (Conventional); and 3) improved surface irrigation and crop management package (Improved). This technology was tested by one farmer in Bradia community.
- Wheat varieties adapted to supplemental irrigation. The varieties tested in the two communities included the bread wheats Mehdia and Achtar and the durum wheats Tomouh and Marjana. Achtar variety represents the farmers' usual practice.
- Optimal planting date. Two farmers in each community were selected to evaluate this technique. Two planting dates were tested. Early planting on 1 November and late planting on 2 December. In general, the late planting date represents the farmers' usual practice.

- Deficit irrigation. To evaluate this technology, three on-farm trials were conducted with three farmers in the Bradia community. The options that were tested were: 1) irrigation at 70% of field capacity and 2) irrigation at 100% of field capacity.

Marginal analysis was used to evaluate the proposed technologies. This aims to determine how the net benefits from an investment (new technology) increases as the amount invested increases. The easiest way of expressing this relationship is by calculating the marginal rate of return, which is the marginal net benefit (the change in net benefits) divided by the marginal cost (the change in costs), expressed as a percentage. The marginal rate of return indicates what farmers can expect to gain on average, in return for their investment when they decide to change from one practice to another (Perrin et al., 1988).

The first step in undertaking an economic analysis of on-farm trials is to calculate the costs that vary for each treatment. Farmers will want to evaluate all changes that are involved in adopting a new technology. It is, therefore, important to take into account all inputs that are affected in any way by changing from one treatment to another. The partial budget is a method of organizing experimental data and information about the costs and benefits of various treatments. Not all production costs are included in the budget, but only those that are affected by the alternate treatments.

Yields from on-farm trials are often higher than the yields that farmers themselves obtain using the same treatment. Consequently, average trial yields must be adjusted downward by a certain percentage to reflect the difference between the experimental yield and the yields on farmers' fields (known as the yield gap) from the same treatment. In this study, the on-farm trials yields were adjusted by 10% downwards for grain and 20% downwards for straw.

6.1.3 Results

Dry conditions

Table 6.1 summarizes the enterprise budget and estimates the farmers' production costs per hectare of wheat. Wheat production costs were similar in the two communities, 5097 Moroccan dirhams (MDh) per hectare in the Bradia community and 4421 MDh per hectare in the Ouled Zmam community. Irrigation costs are the major cost items representing 23% of the total cost in Bradia and 26% in Ouled Zmam. So, any technologies that can save water imply a direct reduction in total production costs. The information that exists in this enterprise budget represents and describes the farmers' practices. This information will be used in the partial budget to evaluate the new technologies.

Marginal analysis
The gross field benefits for each treatment are calculated by multiplying the field price by the adjusted yield (Table 6.2). The gross

Table 6.1: Production costs for wheat in the Bradia and Ouled Zmam communities.

Cost item	Bradia		Ouled Zmam	
	Cost (MDh/ha)	% of total cost	Cost (MDh/ha)	% of total cost
Tillage	600	12	500	11
Fertilization	889	17	1010	23
Planting	995	20	970	22
Crop maintenance	833	16	215	5
Irrigation	1150	23	1146	26
Harvest and storage	630	12	580	13
Total cost	5097	100%	4421	100%

field benefit for the farmers' practice was about 11,663 MDh per hectare. The highest gross benefit observed was 12,795 MDh per hectare and this was associated with the 120 kg N/ha treatment. The total cost that varies for 60 kg N/ha was negative. It means that farmers use more than 60 kg N/ha (106 kg N/ha).The average N quantity that farmers' use in this region is about 63 kg N/ha. The highest total cost that varies involved the 180 kg N/ha treatment (853 MDh/ha).

would incur an additional cost of 45 MDh/ha (453 minus 408), but would realize a loss of 1459 MDh/ha.

Table 6.4 shows that the marginal rate of return (marginal net benefits divided by the marginal cost) for changing from treatment 1 (60 kg N/ha) to treatment 2 (120 kg N/ha) is about 119%. This means that for every 1.00 MDh invested, farmers can expect to recover 1.00 MDh plus a further 1.19 MDh as profit. So,

Table 6.2: Partial budget for nitrogen trials in the Bradia community.

Cost item	Treatments							
	Farmer		60 kg N/ha		120 kg N/ha		180 kg N/ha	
	Straw	Grain	Straw	Grain	Straw	Grain	Straw	Grain
Average yield (kg/ha)	7205	5133	7297	5233	7572	5667	6820	5233
Adjusted yield (kg/ha)	5764	4620	5837	4710	6057	5100	5456	4710
Gross field benefits (MDh/ha)	11663		11880		12795		11781	
Cost of fertilizer (MDh/ha)	729		413		826		1238	
Cost of labor (MDh/ha)	27		17		33		66	
Total costs that vary (MDh/ha)	0		-326		408		853	
Net benefits (for PB) (MDh/ha)	11355		11901		12387		10928	
Net benefits (for EB) (MDh/ha)	6258		6804		7290		5831	

PB = Partial Budget and EB = Enterprise Budget.

Once the net benefit has been determined (Table 6.2), the next step is to perform a dominance analysis. This is done by sorting the treatments, including the farmers' practice, on the basis of costs, listing them from the lowest to the highest, together with their respective net benefits. In moving from the lowest to the highest, any treatment that costs more than the previous one, but yields less net benefit, is said to be 'dominated on the basis of cost' and can be excluded from the analysis.

Table 6.3 reveals that the farmers' practice and the 180 kg N/ha treatment were dominated and can be excluded from the analysis. By switching from 60 kg N/ha to farmers' practice (106 kg N/ha), an additional cost of 326 MDh/ha is incurred but this would lead to a loss of 546 MDh/ha (6804 minus 6258). The value 6258 MDh is the net benefit from the farmers' practices. The same thing for the last treatment, when moving from 120 kg N/ha to 180 kg N/ha, the farmer

from the treatments tested in this nitrogen experiment, the 120 kg N/ha would be the best recommendation for farmers in this region. However, this level is also very close to the current farmers' practice of 106 kg N/ha.

The results in Table 6.5 summarize the economic evaluation of all the technologies tested in the two communities. For example, in the variety trials the new variety Tomouh was shown to have the best agronomic and economic performance in the Bradia community. In the Ouled Zmam community,

Table 6.3: Dominance analysis for nitrogen trials in the Bradia community.

Cost items	Total costs that vary (MDh/ha)	Net benefit (MDh/ha)
60 kg N/ha	0.00	6804.00
Farmer	21.00	6566.00
120 kg N/ha	408.00	7290.00
180 kg N/ha	453.00	5831.00

Table 6.4: Marginal analysis for nitrogen trials in the Bradia community.

Treatment	Total costs that vary (MDh/ha)	Net benefits (MDh/ha)	Marginal cost (MDh/ha)	Marginal benefit (MDh/ha)	Marginal rate of return (%)
60 kg N/ha	0.00	6804			
120 kg N/ha	408	7290	408	486	119

Table 6.5: Technologies to be recommended in the Bradia community.

Trials	Technologies	Variation in cost (%)	Variation in net benefit (%)	Net benefits (MDh/ha)
Varieties	Tomouh	0	37 +	12,331
Nitrogen	120 kg N/ha	8 +	11 +	7290
Planting dates	Early	0	115 +	5526
Deficit irrigation	Farmer	0	0	7996
Improvement of surface irrigation	Improved	40 +	48 +	13,885

the variety that gave the best results was Marjana. The new varieties, Tomouh and Marjana, are both durum wheat varieties. The final year's data confirmed the previous results that the new durum wheat varieties are more water-use efficient than bread wheat cultivars.

The early planting technique showed, for the second year, very interesting results in the two target communities. But this technology can be recommended only to farmers who have access to wells because water is needed for irrigation at seeding.

The econoioc evaluation showed that the technologies to be recommended in Ouled Zman are durum wheat Marjana and early planting (Table 6.6)

In the deficit irrigation trials, no significant difference between treatments was seen for agronomic performance. Results for grain yield and total biomass showed that 70% FC gave as much as 100% FC and farmers' practice because of the high variability noted among samples. However, the economic evaluation showed that the farmer's practice is the best. These results are in sharp contrast to last years' results and to the literature and should be treated with caution.

Wet conditions

Marginal analysis

Table 6.7 presents the partial budget for surface irrigation technology during the wet year. The gross field benefit for each treatment was calculated by multiplying the field price by the adjusted yield. The gross field benefit for the farmer's practices was about 14,427 MDh per hectare. The highest gross benefits observed were using the improved treatment (20,927 MDh/ha). Farmer's practice was used as a basis for the analysis and, therefore, the total cost that varies for this technology equaled zero. The highest total costs that varies involved the improved treatment (2000 MDh/ha).
Table 6.8 shows that the marginal rate of return (marginal net benefits divided by the

Table 6.6: Technologies to be recommended in the Ouled Zmam community.

Trials	Technologies	Variation in cost (%)	Variation in net benefit (%)	Net benefits (MDh/ha)
Varieties	Marjana	0	222 +	6970
Planting dates	Early	5 +	95 +	9665

Table 6.7: Partial budget for surface irrigation improvement trials in the Bradia community.

Cost item	Treatment					
	Farmer		Conventional		Improved	
	Straw	Grain	Straw	Grain	Straw	Grain
Average yield (kg/ha)	7960	6450	8560	7180	9890	9530
Adjusted yield (kg/ha)	6368	5805	6848	6462	7912	8577
Gross field benefits (MDh/ha)	14426		15996		20926	
Cost of surface leveling (MDh/ha)	0		600		2000	
Total costs that vary (MDh/ha)	0		600		2000	
Net benefits (for PB) (MDh/ha)	14426		15396		18926	
Net benefits (for HB) (MDh/ha)	9385		10355		13885	

marginal cost) for changing from treatment 1 (Farmer) to treatment 2 (Conventional) was 162%; and from treatment 2 to treatment 3 (Improved) it was 252%. This means that for every 1.00 MDh invested, farmers can expect to recover their investment plus an additional 2.52 MDh. So, from this experiment, we can conclude that the improved technique would be the best recommendation for farmers in this region.

Results in Table 6.9 summarize the economic evaluation of all the technologies tested in the two communities. For the deficit irrigation, planting dates and nitrogen trials marginal analysis was not needed because changes in costs that vary are equal to zero or negative. For example, irrigation at 70% of field capacity in the deficit irrigation trials involved a reduction in total cost of 10% and an increase in net benefits of 45%. In this case, only dominance analysis is needed and any treatment that has net benefits that are less than or equal to those of a treatment with lower cost that varies is dominated. The marginal rate of return must be always positive. The best recommendations for farmers in the Bradia community according

Table 6.8: Marginal analysis for surface irrigation improvement trials in the Bradia community.

Treatment	Total costs that vary (MDh/ha)	Net benefits (MDh/ha)	Marginal cost (MDh/ha)	Marginal benefit (MDh/ha)	Marginal rate of return (%)
Farmer	0.00	14426			
Conventional	600	15396	600	970	162
Improved	2000	18926	1400	3529	252

Table 6.9: Technologies to be recommended in the Bradia community.

Trials	Technologies	Variation in cost (%)	Variation in net benefit (%)	Net benefits (MDh/ha)
Varieties	Marjana	2 +	30 +	9615
Nitrogen	60 kg N/ha	0	35 +	9986
Planting dates	Early	8 -	55 +	12,869
Deficit irrigation	70%	10 -	45 +	7580
Improvement of surface irrigation	Improved	40 +	48 +	13,885

to the economic evaluations are Marjana durum wheat variety, 60 kg N/ha, early planting date, irrigation at 70% of field capacity and improved surface irrigation. Table 6.9 also shows that the recommended technologies imply a considerable increase in farmers' net benefits (between 30 and 50%) because of the very high agronomic performance of the technologies tested.

In Ouled Zmam community (Table 6.10) Achtar bread wheat variety and early planting date are the treatments to be recommended.

6.1.4 Conclusions

- The economic performance of some technologies changes from year to year due to drought conditions (nitrogen-use technologies). This makes the technology recommendation process very difficult.
- The new durum wheat varieties are more water-use efficient than bread wheat varieties.
- The early sowing technique is one of the water-use efficiency technologies to recommend to farmers in the two communities.
- In all cases, the change in technology offers a rate of return above 100% (considered as a minimum rate of return acceptable to farmers).
- The adoption of the tested technologies implies a substantial increase in farmers' net benefits (between 110 and 222%) because of the very high agronomic performance of the technologies tested.
- Marginal analysis is an important step in assessing the results of on-farm experiments before making recommendations. But agronomic interpretation and statistical analysis are also part of the assessment.

6.2 Adoption improved technologies

6.2.1 Introduction

This part of the report is concerned with a study of the adoption of efficient water-use technologies and the farmers' attitude toward these technologies. This study was carried out with the two Benchmark communities, Bradia and Ouled Zmam. The study included farmers who participated in field days and farmers who hosted field trials. The technologies evaluated were wheat varieties adapted to supplemental irrigation, deficit irrigation, optimal planting date, and optimal rate of nitrogen.

Field days were organized each cropping year during the three years of the project and served as an occasion for interaction between researchers, extension agents from ORMVAT and farmers. During the field day, the host farmer played the lead role in presenting his activities to other farmers (what was tested in his field and how the efficient water-use technologies were performing). This gave farmers an opportunity to learn from and convince each other. Researchers and extension staff assisted farmers in answering questions and clarifying issues. Meetings with farmers and individual contacts were also occasionally organized to exchange ideas on proposed new technologies and to prepare for the installation of trials on the farmer's plots.

6.2.2 Methodology

The efficient water-use technologies discussed in the adoption and impact evaluation are the same technologies already explained in the economic evaluation part of this chapter.

Table 6.10: Technologies to be recommended in the Ouled Zmam community.

Trials	Technologies	Variation in cost (%)	Variation in net benefit (%)	Net benefits (MDh/ha)
Varieties	Achtar	0	0	5195
Planting dates	Early	2 -	48 +	5811

Sampling procedure

The farmers sample included three categories of farmers, those who participated in field days, those who hosted trials and their neighbors. A total of 50 farmers were interviewed. The sample included 40 farmers who participated in field days (including farmers who are neighbors of the field trials farmers). This sample represents more than 50% of the total participants in field days during the three years of the project and 10 farmers who hosted trials.

The team responsible for collecting the data was composed of interviewers from ORMVAT (extension agents) and INRA (technicians). Before starting the survey, the questionnaire was pre-tested and the interviewers were trained on how to use the questionnaire. The training included discussion of the survey objectives, a review of the survey questionnaire and role-playing.

Adoption indicators

Two main indicators of adoption were used in this study:

- **Adoption rate**: This indicator represents the percentage of farmers adopting the technology under consideration. It is an important indicator in measuring technology adoption, especially during the early stages of the project.
- **Degree of adoption**: This is measured using the proportion of land under the new irrigation technique or new crop cultivar, for example.

6.2.3 Results

Characteristics of the farmer sample

The characteristics of the farmer sample are presented in Table 6.11. This table shows that there was little difference between the two categories of farmers for the majority of variables listed. We found no statistical difference in years of schooling between the two categories and the majority were illiterate. Household sizes were also not significantly different. On average, each family was composed of 3.6 adult males, 3.4 adult females and 2.9 children under 15-years old. However, the number of farmers who used underground water for irrigation was statistically significantly different between field day participants and field trial hosts. This difference can be explained by the fact that one of the criteria for choosing plots for the optimal planting date trial was the existence of a well. The size of livestock flocks and the number of tractors owned are generally correlated with farm size.

Table 6.11: Characteristics of sample farmers by categories.

Characteristic	Field day participants	Field trial hosts	Difference between the two categories
Male (%)	100	100	NS
Female (%)	0	0	NS
Age (yr)	57	55	NS
Formal education (%)			
None	72	78	NS
Traditional school	18	16	NS
Primary school	7	4	NS
Secondary school	2	2	NS
Adult females (no.)	3.5	3.3	NS
Adult males (no.)	3.7	3.5	NS
Children < 15	3.0	2.8	NS
Farm size (ha)	5.6	7.4	NS
Wells (%)	22	46	S
Sheep (no.)	10.3	20.5	S
Cattle (no.)	2.3	4.4	NS
Tractor (%)	9	12	S
Number of farmers	40	10	

Note: NS = not statistically significant; S = statistically significant at the 95% confidence level.

Adoption rate and degree of adoption

The results of farm surveys of participants in the demonstration trials showed that the level of adoption of new varieties of wheat adapted to supplemental irrigation in the two communities was very high. Ninety-eight percent of farmers who hosted demonstration trials used new varieties of wheat and 52% of their total wheat area was sown to such varieties (Table 6.12).

These results also indicated that 52% of participants in field demonstrations adopted the optimal planting date technique. The degree of adoption among this group was 67%. In contrast, only 10% of participants adopted deficit irrigation technology. Farmers are apparently not convinced that stressing the crop can improve land and water productivity.

In general, adoption rates and degrees of adoption for participants in field days were very low when compared to the results obtained for participants in demonstration trials. The field participant group faces more challenges in adopting these technologies and progresses more slowly than farmers who hosted the trials.

The results presented in Table 6.13 indicate that just 36% of all participants in field days and neighbors of demonstration trial hosts use the proposed new wheat varieties. The degree of adoption of these varieties for the same group of farmers was about 25%. Obviously, the adoption rates of the optimal rate of nitrogen and optimal planting date were very low compared to rates for wheat varieties adapted to supplemental irrigation. The adoption rate for deficit irrigation technology was zero.

Table 6.14 shows that most farmers found it very easy to adopt the proposed new varieties that use irrigation water more efficiently (85%) and the optimal planting dates (87%). But farmers found it difficult to adopt the optimal rate of nitrogen and deficit irrigation recommendations. These procedures are quite different from those they replace and a special information program is needed to markedly reduce the degree of complexity of these technologies.

In general, the more accessible and simple the information about a technology is, the less time is needed between learning about it and its adoption. For example, by just after the first year of demonstration trials, 85% of farmers had adopted the wheat varieties adapted to supplemental irrigation. But for the optimal rate of nitrogen, which is considered a more complicated technology (as it needs soil analysis and exact rate

Table 6.12: Adoption rate and degree of adoption by participants in demonstrations.

Indicators	Varieties	Optimal rate of nitrogen	Optimal planting dates	Deficit irrigation
Adoption rate (%)	98	26	52	10
Degree of adoption (%)	52	62	67	25

Table 6.13: Adoption rate and degree of adoption by participants in field days and neighbors of demonstration trial hosts.

Indicators	Varieties	Optimal rate of nitrogen	Optimal planting dates	Deficit irrigation
Adoption rate (%)	36	11	5	0
Degree of adoption (%)	25	20	50	0

Table 6.14: Technical feasibility of the proposed technologies (in %).

Degree of feasibility	Varieties	Optimal rate of nitrogen	Optimal planting dates	Deficit irrigation
Very easy	85	8	23	5
Easy	9	13	64	13
Moderate	5	21	9	14
Difficult	1	53	4	68
Very difficult	0	5	0	0

calculation), the majority of farmers started adoption after the second year of demonstration (Table 6.15).

To study the economic impact of the efficient water-use technologies proposed by the Benchmark project, we used the economic water productivity indicator (MDh/m^3). An increase in economic water productivity implies a direct improvement in farmers' incomes. It is also positively correlated with water productivity. The precise impact of the adoption of the proposed efficient water-use technologies on farmers' incomes will not be evaluated in this report.

The results in Table 6.16 indicate that on average the adoption of the technological package increased economic water productivity by 30%. The highest level of economic productivity was with the deficit irrigation technology; this implies that the maximum yield obtained with full irrigation does not always correspond to the maximum economic water productivity.

Table 6.15: Time between learning about the technology and its adoption (in %).

Period	Varieties	Optimal rate of nitrogen	Optimal planting dates	Deficit irrigation
One year	68	12	0	0
Two years	23	56	73	0
More than two years	9	22	27	100

Table 6.16: The impact of adoption on economic water productivity.

	Varieties	Optimal rate of nitrogen	Optimal planting dates	Deficit irrigation	Technological package
Economic water productivity before adoption (MDh/m^3)	2.25	2.25	2.25	2.25	2.25
Economic water productivity after adoption (MDh/m^3)	2.63	2.75	2.55	3.75	2.92
Variation (%)	17	22	13	67	30

6.2.4 Conclusions

The adoption study of improved water-use technologies showed that:

- On average, the adoption rate and degree of adoption for all tested technologies by participants in demonstration trials are promising (average 35%).
- For participants in field days, and their neighbors, adoption rates are lower than for hosts of the trials. One of the reasons for these low rates is the misunderstanding of some technologies.
- Other factors affecting these rates, such as property right aspects, must be studied
- More involvement of the Water Users' Association in the dissemination process is needed.
- ORMVAT and INRA must work more closely together.