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SUMMARY – This paper explains the results and conclusions of the evaluation of land and water management technologies carried out in the MEDRATE project. Three technologies (reduced tillage, water harvesting and supplementary irrigation) are analysed at research, on-farm trial experimentation and farmers' utilisation levels. Present technological problems and alternatives are presented as an introductory background and finally some positive and negative aspects for the integration of these technologies are discussed.

Key words: Mediterranean, rainfed agriculture, land, water, management, technologies.

***RÉSUMÉ –** "Technologies pour la gestion de la terre et de l'eau". Cet article explique les résultats et les conclusions de l'évaluation des technologies de gestion de la terre et de l'eau menée dans le cadre du projet MEDRATE. Trois technologies (labour réduit, collecte d'eau et irrigation supplémentaire) sont analysées au niveau de la recherche, des essais expérimentaux à la ferme et de l'utilisation par les fermiers. Les problèmes technologiques actuels ainsi que les alternatives sont présentés comme contexte d'introduction et finalement certains aspects positifs et négatifs pour l'intégration de ces technologies sont discutés.*

***Mots-clés :** Méditerranée, agriculture pluviale, terre, eau, gestion, technologies.*

Present technical problems and alternatives for the group of technologies

The Mediterranean area is specially characterised by its aridity. Arid and semi-arid conditions are typical throughout the region and an important feature of the climate is the low and irregular distribution of rainfall. Occurrence of drought events is common during all seasons and limits crop and livestock productions. Rainfall efficacy can be very low because of its high intensity and low soil infiltration. Winds in some areas aggravate the negative conditions for high evapotranspiration. Cold winters and very hot summers are common and frost in late spring can be followed by early drought before summer.

Soils are poor due to their recent development and because climatic conditions do not favour high natural plant biomass production. For this reason levels of soil organic matter are low and intensive management of this soil by agricultural practices during the past two-three thousand years aggravated these conditions. Soil erosion is an important problem and desertification is increasing. Salinity and alkalinity are also common in many areas. Shallow soils are typical and water-holding capacity remains insufficient to maintain productivity of agriculture.

All these characteristics of climate and soils make this area marginal for productivity. The water balance is negative many times during the cropping season and agriculture is compromised by the water availability for crop and animal production. Thus, water is the main limiting factor for crop production in these areas. For crop production, water has to be accumulated and stored in the soil and absorbed during the crop cycle, thus, water and soil and their management play the most important role for development of the crops in these areas.

Soil and water can be managed using newly adapted technologies to improve the potential in these agricultural systems. Since the beginning of agriculture in this area, some techniques have been used by farmers but should be optimised to improve sustainability. Cropping systems are based on the traditional management of winter cereals, olive and almond crops that can lead to land degradation. Intensive tillage is common to seedbed preparation and should be adapted to the conditions of the arid and semi-arid environments for a better conservation and use of the limited soil moisture.

Social and economic features in the region such as high age of the farmer, land tenure, fragmentation of land holdings, low educational level and low capacity for investment, especially for the small farmers, are other important constraints.

Nowadays, wide possibilities are open through the knowledge and progress of science and technology. In fact, mechanisation and industrial goods can be used to support some technologies that optimise soil and water management. Alternatives should consider the farmer's desire to minimise the economic risk inherent to the limiting conditions of the area and should take in account the environmental impact that could make these agricultural systems unsustainable. Continuous involvement of public institutions is needed in research projects and technology transfer systems have to be improved and adjusted. Involvement of the private sector is also important and should be encouraged.

Many technologies for soil and water management could be considered. However, we described and analysed only three promising technologies that we consider can be used in the development and sustainability of agricultural systems. These technologies are: conservation and reduced tillage, supplementary irrigation and water harvesting.

Technology 1: Conservation and reduced tillage (including no-tillage)

Description of the traditional/conventional technology (CT)

Conventional or traditional system is defined in all selected areas as that which is used by the farmer that includes a high level of soil disturbance in a cycle of operations such as subsoiling or mouldboard ploughing, following several disking, harrowing, chiselling operations or other tillage methods.

In orchard crops, the tillage system considered was spading in autumn to plough under fertilisers and skim ploughing (1-2) in summer for weed control**.**

Objective of the alternative technology

The objective of this type of technique is the reduction or simplification of tillage operations following the aims of conservation tillage in order to obtain ecological, agronomical and economic advantages, specifically in water and soil conservation.

Description of the alternative technology (TE)

In all cases, alternative systems are defined as: (i) Reduced tillage or Minimum tillage consisting of one or two shallow harrowing operations before sowing that maintain enough crop residues to be considered as conservation tillage; and (ii) No tillage and Direct drill, where there is a minimal soil disturbance. Residues remain on the soil surface or in some cases they are totally or partially removed. Weed control is carried out through spraying a non-selective-non-residual herbicide before sowing. A special no-till drill is used for sowing annual field crops.

Summary of results

At research and experimental level. On-farm trials

In most cases, several short and medium term experiments have been carried out under the different particularities of the selected areas. In all field crop experiments, treatments compared the performance of traditional/conventional tillage systems with that of a reduced or no-tillage system. In some cases, where experiments involved trees (olive, almond or vineyards), a comparison between conventional (deep or shallow tillage) and no tillage, maintaining a live or dead cover on the soil, was planned. Several experiments included treatments of nitrogen or phosphorus fertilisation rates, tillage time, sowing time, sowing rate, or performance of the system under different crop rotations.

The summary of results is presented in Tables 1 and 2. Tillage reduction did not always affect yield, but it did entail positive effects. High variations were found between and within selected areas due to the specific cropping systems and environmental factors. More important than yield is its stability, which is very positive when this alternative technology is used.

Water use by crop is not generally higher when conservation tillage technology is used. Nevertheless, information from queries shows that there is an improvement of WUE up to 31 % when conservation tillage technologies are used.

Not much data from research studies is available about the quality of the product. Only grain weight increased when conservative technologies were applied.

From available data, high variation can be found in the production cost, comparing conventional technologies with conservation and reduced tillage systems (Table 1). In some cases, production cost is a disadvantage when reducing tillage because of the negative implication of weed control. However, looking for positive data concerning economic margin, reduction in fuel and labour compensate the probable additional expenses in alternative systems, making these technologies much more beneficial.

Environmental impact is assessed in Table 2, and it is a merely qualitative estimation from the researchers in the selected area of this study. Over all study areas, there is a general agreement in that soil loss (SL) has been dramatically reduced when alternative technology is used. More crop residues (CRA) and more soil cover from this residue (CRC) are commonly found when reduced and no tillage systems are used; but there is some variation depending on the total biomass production. Reduction of leaching (L) and improvement of soil organic matter (SOM) have been appreciated as normal in some farming systems. Impact of pests and diseases (PDI) is highly variable and dependent of the particular insect or disease. The increment in use of agrochemicals (AgU) is general when alternative technology is used, commonly due to more difficulties for weed control.

Table 2 shows some points referring to social aspects. According to researchers and technical advisers' appreciation, social acceptance (SA) of these techniques is highly positive. The same level is shown in feasibility of the technology (TF), with the exception of crop trees where more specific training is needed. Indeed, there is a general recognition that the use of reduced and especially no tillage-direct drilling need some training for producers and farmers.

At farmer level. On-farm surveys

The surveys at user level have been carried out in three countries: Egypt (9), Italy (6) and Spain (24). The average age of the farmers is 44 years and their educational level varies depending on the country; but most farmers reached secondary school level and even 10% had been to university. In Egypt, 55% of the surveyed farmers are illiterate.

Farmers have been using these techniques between 4 and 13 years and they appreciate an increment of yield from 15 to 30% without any gain in the quality of the product. They recognise the high value of the alternative technology because of the reduction of labour (50% of the time), reduction of mechanisation power (up to 30%) and reduction of inputs (up to 25%).

There are differences between users concerning the investment needed (medium to high), but in all cases, the general opinion is that there is 20% lower investment in the use of conservation tillage in comparison with conventional systems.

Eighty two percent of farmers recognise the positive environmental impact when tillage is reduced.

Table 1. Range of differences (%) between Reduced-No tillage and Conventional tillage technologies in yield, yield stability, water use, water use efficiency (WUE) and economic results from the analysis in the selected areas

Selected area	Crops[†]	Yield (%)	Yield stability (%)	Water use (%)	WUE	Quality[††]	Production cost (%)	Margin (%)
Algeria	FC	+19	–	+33.7	–	+GW	-58	-21.3
Egypt	FC	?	?	?	?	+GW	?	?
Italy	FC	-2	–	=	–	+GW, +PC	-20	+17
Italy (vineyard)	TC	–	–	–	–	–	+18.5[†††]	-6.2[†††]
Italy (olive)	TC	-6.2	+25 to +47	–	–	–	+4.2[††††]	+13.2[††††]
Morocco	FC	Up to +27	-11 to +40	-2 to -3.5	Up to 31.5	–	-10	247
Morocco	FC	Up to +75	Up to +54	–	–	–	-10	247
Spain	FC	-28 to -13	–	=	Up to -27	-GW, -PC	-30	+1
Spain	FC	+21 to +26	+28 to +78	-4.5 to 6.0	Up to +10	+GW	-4 to -10	Up to 27.5
Syria	FC	-14.5 to +2.4	-10	=	Up to -13.5	–	-20	–
Syria	FC	+4.5 to +6.4	–	–	Up to 6.3	–	–	–
Turkey	FC	-3 to +21	–	= to +19	-7 to +31	HR	11 to 100	1 to 50

[†]FC: field crops (winter cereals, chickpeas, legumes); TC: tree crops (olive, almond and vineyard).
[††]GW: grain weight; PC: protein content; HR: high range between treatments.
[†††]Vineyard production and cover crop between rows.
[††††]Olive production and cover crop between rows.

Table 2. Range of qualitative differences (from -3 to +3) between Reduced-No tillage and Conventional tillage technologies for different aspects from the analysis in the selected areas[†]. Qualitative estimation, positive or negative, compared to the control: -3 = high negative; -2 = medium negative; -1 = low negative; 0 = null; +1 = low positive; +2 = medium positive; +3 = high positive

Selected area	Crops[††]	BL	SL	CRA	CRC	L	AgU	SOM	PDI	TF	NT	GI	SA
Algeria	FC	–	-1	0	–	-2	–	–	–	+3	+3	–	+2
Egypt	FC	–	–	–	–	–	–	–	–	–	–	–	–
Italy	FC		-3	+1	+2	-1	+1	+2	-1 to +1	-1 to +1	+2	0	+2
Italy (vineyard)	TC	–	-3	–	+2	-1	-1 to +1	+2	0 to +1	-1 to +1	+2	0	+2
Italy (olive)	TC	–	-3	–	+2	-1	-1 to +2	+2	0 to +1	-1 to +1	+2	0	+2
Morocco	FC	–	–	–	–	–	–	–	-2	+1	+2	-2[†††]	+2
Morocco	FC	–	–	–	–	–	–	–	-2	+1	+2	-2[†††]	+2
Spain	FC	–	+2		-1	+1	–	+1	-1 to +1	+2	+1	0	-3 to +3
Spain	FC	–	-2	+1	+2	-1	+1	+1	-1 to +1	+2	+1	0	-3 to +3
Syria	FC	–	–	-1	–	–	–	–	-1 to +1	+3	+1	0	+1
Syria	FC	–	–	–	–	–	–	–	–	+2	+1	0	+2
Turkey	FC	–	-2 to -3	+1 to +2	+1 to +2	–	0 to +3	–	0 to +1	+2 to +3	+2	–	+1 to +3

[†]BL: biodiversity loss; SL: soil loss; CRA: crop residue amount; CRC: crop residue cover; L: leaching; AgU: agrochemical use; SOM: soil organic matter; PDI: pest and disease impact; TF: technical feasibility; NT: need for training; GI: gender impact; SA: social acceptance.
[††]FC: field crops (winter cereals, chickpeas, legumes); TC: tree crops (olive, almond and vineyard).
[†††]In relation to livestock production.

Access to technology has been easy for farmers, who also found a high level of assistance from Extension and Research Services. The diffusion of the technology from farmers to other farmers is only 23%. The need for training is medium.

Alternative technology is well accepted and farmers recognise the positive impact on the well-being of the community.

Surveys of non-users were carried out in Egypt (8), Morocco (15) and Spain (15) with an average age of 51 (elder than users). The level of instruction is also lower, and only 15% of the farmers had reached secondary school and 15% are illiterate. Disadvantages of the alternative technology for non-users are high investment, high inputs (herbicides), technological difficulty, and low to medium degree of knowledge of the technology.

Similarity and differences between sites

In general terms, this technology is broadly extended and is similar for all places. Reduction of tillage to no-tillage is defined as conservation tillage if crop residues cover more than 30% of the soil. Differences are due to different tools, and minimum tillage or no tillage itineraries are used locally.

Conclusions

Improvement

(i) Increase of general productivity.

(ii) Improvement of water balance when there is a general increase of opportunity for infiltration, reduction of runoff and evaporation that lead to an increase of soil water content, crop water availability and water use efficiency.

(iii) Increase of the amount of crop residues that cover the soil surface. This is also advantageous for erosion control and for the increase of soil organic matter content. In some very particular cases, there is a reduction of weed seed bank that is useful for weed control.

(iv) Economic margin is improved due to less fuel and labour utilised in this alternative technology.

Disadvantages/limitations

(i) Incidence of pests (as Hessian fly), diseases (as Snow mould) and weeds (as *Convolvulus* and *Bromus*). More accurately weed control. Specific application of herbicides and higher rates in some cases.

(ii) In some circumstances infiltration is reduced due to compaction of the soil surface. In particular conditions, continuous addition of crop residues lead to stubble and residue accumulation, making planting operations and seedling emergence more difficult. With the use of these techniques that are based on maintaining crop residues, less of this material can be used for livestock feeding and bedding. Stubble grazing is also reduced.

(iii) It is detected that a specific drill is needed, and farmers have difficulties acquiring this machinery.

(iv) Limitations have been detected in the implementation in some countries. Some chisels and specifically direct drill machines are not available. The supplies do not arrive and the price of the machinery is high. This situation makes the farmers not accessible to the alternative technology. The problem is worse when the landholding is small. Sometimes the power of the tractor is small and makes it unsuitable for the new equipment.

(v) Soil compaction is another very common limitation where clay and heavy texture is present and also when sheep grazing is practised under wet conditions.

(vi) High accumulation of residues can produce physical and allelopathic problems.

Conditions of use

(i) Maintaining all residues chopped on the soil surface is very useful for an optimum crop residue management. In some cases, when the yield of residues is high, part has to be removed to facilitate seedbed preparation. However, when it is low, more residues have to be applied or minimum tillage use is more recommended than no tillage.

(ii) In some cases, it is important to delay sowing time to prevent effects of pests and better control of specific weeds. It is also important to prevent grazing when the soil is wet in order to limit compaction.

(iii) For adoption and recommendation within a crop system perspective, crop rotation, forage crop production and livestock management at farm level should be taken into account.

Recommendations

(i) This alternative technique can be widely recommended in the soils of these areas, however it should be experimented locally to determine the best conservation tillage system. Sometimes a special drill should be manufactured locally. Some specific machinery requires powerful tractors (110 HP).

(ii) In some cases minimum tillage is a better option than no-till to conserve soil and water. In some situations once every three-four or several years, depending on the situation, a disk plough could be used to bury crop residues (stubble, straw, and weeds). If crop residues are not grazed or bailed, once every three to five years, the residue should be removed or even burnt.

(iii) There is a need for specific research to identify farms and their socio-economic characteristics, that could adopt the system. There is also a need for specific transfer of technology programmes to promote knowledge and development.

Technology 2: Water harvesting

Description of the traditional/conventional technology (CT)

In the selected area of Egypt, conventional technology is defined as broadcasting wheat seeds after two ploughing operations.

In the selected area of Tunisia, conventional or traditional system is the growing or cropping areas for grazing or occasional winter cereal production without collection of rainwater.

Objective of the alternative technology

The objective of this type of technique is to make maximum use of runoff for supplementation of crops and trees with rainfall/runoff water and for the recharging of groundwater aquifers.

Description of the alternative technology (TE)

Selected area of Egypt: catchment area for water harvesting with a design of alternate bare strips for surface runoff to the cropped area.

Selected area of Tunisia: water harvesting techniques (*jessours* and *tabias*) are small earthen dams installed on the runoff watercourses to capture water and soil (sediments).

Summary of results

At research and experimental level

Data for evaluation of these techniques come from selected areas of Egypt and Tunisia. Researchers and advisers have filled in only two questionnaires. There were important differences in experimental design implemented in the two areas. In one case, water is collected in bare alternate strips with very low infiltration that promotes runoff of the rainfall to the cropped areas. In the second case, water is harvested by the installation of small check dams along the watercourses of the watershed.

In all cases, improvement of yield has been reported by the introduction of alternative technology by up to 72% in Tunisia. No available data from water use and water-use efficiency is reported in the research survey done in the selected areas, but water availability for crops, depending on the techniques, has been improved by up to 82% more than in conventional uses (Tables 3 and 4).

Production costs of the alternative technology are higher than in conventional practice; but up to 30% more economic margin is obtained.

A positive effect on erosion control, increase of soil organic matter and less leaching has been reported in Tunisian experiments.

Technical feasibility and social acceptance are good; but in the opinion of researchers and advisers, some training is needed for a better use.

At farmer level. On-farm surveys

Users have been surveyed in two countries, Egypt (9) and Tunisia (72). The average age of farmers is 61 years. Educational level is very low and most farmers reached only primary school (42%) and 53% of them are illiterate. Manual labour is practised in 75% of cases and low mechanisation is frequent. In Egypt the crops are pastures and in Tunisia they are barley and tree crops.

Farmers have been using these techniques in Tunisia for many years, but in Egypt, they are relatively new. In Tunisia, farmers appreciate a slight increase in yield and equal or better quality of the product. However, in Egypt, no improvement has been noticed. The age, educational level of the farmer and his income are the characteristics that make a distinction between users and non-users.

In both cases, investment is medium and more labour is needed. A farmer in Tunisia finds the alternative technology easy to use, but it is very difficult for Egyptian farmers. In both cases training is needed. Access to technology has been through other farmers (21%) and Extension Services with less importance. However half the farmers received training or assistance from Extension Services for planning and organisation.

Adoption level of the alternative technology is high or very high and it is well accepted and positively considered by the community.

Data on non-users was collected only in Egypt and the main reasons for refusing the utilisation of this technology are high investment, low results and high inputs.

Similarities and differences between sites

The way of using both the alternative and traditional technologies is different in the 2 selected areas.

Conclusions

Improvement

(i) Yield is improved.

Table 3. Range of differences (%) between treatments with applied water from harvesting to treatments without this water applied in yield, yield stability, water use, water use efficiency (WUE) and economic results from the analysis in the selected areas

Selected area	Crops[†]	Yield (%)	Yield stability (%)	Water use (%)	WUE	Quality[††]	Production cost (%)	Margin (%)
Egypt	FC	+12.8	+12.7	–	–	–	+30	+25
Tunisia	FC	+15	–	–	–	–	+35	+30

[†]FC: field crops (winter cereals, chickpeas, legumes).
[††]GW: grain weight; PC: protein content; HR: high range between treatments.

Table 4. Range of qualitative differences (from -3 to +3) between treatments with applied water from harvesting to treatments without this water applied for aspects from the analysis in the selected areas[†]. Qualitative estimation, positive or negative, compared to the control: -3 = high negative; -2 = medium negative; -1 = low negative; 0 = null; +1 = low positive; +2 = medium positive; +3 = high positive

Selected area	Crops[††]	BL	SL	CRA	CRC	L	AgU	SOM	PDI	TF	NT	GI	SA
Tunisia	FC	–	+2+3	–	–	0	0	+2	–	+2	+1	0	+3

[†]BL: biodiversity loss; SL: soil loss; CRA: crop residue amount; CRC: crop residue cover; L: leaching; AgU: agrochemical use; SOM: soil organic matter; PDI: pest and disease impact; TF: technical feasibility; NT: need for training; GI: gender impact; SA: social acceptance.
[††]FC: field crops (winter cereals, chickpeas, legumes).

(ii) Soil moisture content is higher. Ground water recharge is increased and water availability is improved.

(iii) There is control of flooding and erosion risk is strongly reduced.

(iv) Economic margin is better and net return by ha increases.

Disadvantages/limits

(i) High reliability on rainfall regime. Rainfall runoff may occur with increasing catchment area.

(ii) Less grazing lands. However, catchment continues to be used for grazing by small sized cattle herds.

(iii) Limitation in the selected area in Egypt is that increasing the catchment/cultivated area ratio can decrease land use efficiency. However, because WUE is increased, 1:1 is recommended.

(iv) In Tunisia the limitation is that sufficient catchment (collection areas) should be prepared and it is better adapted to areas with a relatively high slope.

Conditions of use

(i) For selected area in Egypt: bare soil strips (catchment area) have to be left for surface runoff on a gentle slope (0.5-1.0%). Low rainfall (<200 mm).

(ii) For selected area in Tunisia: relatively sloped lands receiving more than 100 mm/year have to be used.

Recommendations

(i) In selected area of Egypt, this technique can be widely recommended for gentle slopes (0.5-1.0%) and low rainfall (<200 mm).

(ii) For selected area of Tunisia, some engineering design parameters should be improved. Optimal partitioning of runoff water between upstream and downstream areas and between different end users (irrigation, industry, drinking, etc.) have to be ensured.

Technology 3: Supplementary irrigation

Description of the traditional/conventional technology (CT)

No irrigation is done and crop growth relies on rainfall.

Objective of the alternative technology

The objective is to increase and stabilise yield in arid and semi-arid regions with a supplementary application of irrigation water. This water should be applied at the most sensitive development stages of the crop.

Description of the alternative technology (TE)

Supply of one, two or several applications of water during the crop cycle at specific-sensitivity growth stages.

Summary of results

At research and experimental level. On-farm trials

Several experiments of medium duration (4 to 6 years) were carried out under different particular features of the selected area. In all experiments, treatments comparing the performance of crops at different rates and time of water application with no irrigated treatment that received only rainfall. Some experiments included comparison between drip and sprinkler systems with surface irrigation. Part of the data are from field crops like wheat, and in other cases the experiment was done with almond and olive tree crops. Several experiments included treatments such as cultivars, nitrogen fertilisation rates or sowing time.

Yield and yield stability is clearly improved when supplementary irrigation is applied (Table 5). Considering that these areas have high water deficit, it is logical to understand that application of water can raise yield up to 100 or 300%. High variations were found between selected areas due to the specificity of treatments and crops where technology was used.

As more water is available to the crop, depending on the application rates, more water is used. Water use efficiency is often improved (up to 80%); however there were some situations without improvement or even negative effects (Table 5).

The fruit weight was improved up to 45%, but not the protein content (Table 5).

In general, this technology needs investment and the cost of production is high. However economic margin is much higher, making it very interesting and appreciated by farmers.

Only a low environmental impact is detected in relation with leaching. Leaching only occurs when high rates of water are applied (Table 6). In a few cases some erosion can be produced. One query detected a negative impact due to the incidence of pests and diseases when water is applied.

In all cases, researchers and advisers pointed out that supplementary irrigation has high technical feasibility. However for the development of the technology, training of farmers is recommended. The very positive effect of the technology is its high social acceptance by farmers, which makes it very promising.

At farmer level. On-farm surveys

Farmer users of this technology were surveyed in Egypt (9) and Spain (16). The average age of farmers is 47 years and educational level is high in Spain and low in Egypt, where 50% of the farmers are illiterate and where only 22% reached secondary school.

Adoption of the technology by users is high (12%) to very high (64%) and is well accepted by farmers. The increase of yield is the main reason for the adoption and in Spain the increase of yield in tree crops is up to 300%. The cost and expenses are high but economic margin is better. Farmers qualify the investment need as medium (57%) to high (20%).

Only 8% of farmers think that this technology is difficult to adopt; however 40% find some specific technological difficulties and 36% have problems with organisation and marketing.

Training is needed for 71% of surveyed farmers and degree of mastering of the technology varies greatly between users. Seventy seven percent of Egyptian farmers find the technique very difficult and 87% of Spanish farmers find it easy to use.

The access to the technology has been through extension services (52%) and other farmers. Fifty six percent of farmers received assistance, first from extension services, then from research services and finally from private companies.

This technology has been strongly adopted and accepted due to the improvement of the well being of the community.

The differences between non-users are the higher age of farmers (average of 62 years old), lower education level, much lower gross income and smaller size of the farm.

Table 5. Range of differences (%) between application of water as supplementary irrigation and no irrigation in yield, yield stability, water use, water use efficiency (WUE) and economic results from the analysis in the selected areas

Selected area	Crops[†]	Yield (%)	Yield stability (%)	Water use (%)	WUE	Quality (%)	Production cost (%)	Margin (%)
Egypt	FC	+35 to +68	–	–	–	+25 to +45[††]	–	–
Morocco	FC	+20 to +113	–	+20 to +70	+2 to +37	-3 to +15[††]	–	–
Spain	TC (olive)	+55 to +90	–	–	+30 to +80	+6 to +20[††]	+30 to +55	+64 to +96
Spain	TC (olive)	+49	+24	–		+4 to 26[††]	+59	+34
Spain	TC (almond)	+337	–	–	+71	+3 to +17[††]	+61	+349
Syria	FC	+37 to +81		+25 to +143	-3 to +23	+12 to +17[††] -13 to -15[†††]	–	–
Turkey	FC	0 to +30	–	-12 to +46	-13 to +28	-12.3 to +1[†††]	-46 to +177	-52 to +150

[†]FC: field crops (winter cereals, chickpeas, legumes); TC: tree crops (olive, almond and vineyard).
[††]Grain weight or fruit weight.
[†††]Protein content.

Table 6. Range of qualitative differences (from -3 to +3) between application of water as supplementary irrigation and no irrigation for different aspects from the analysis in the selected areas[†]. Qualitative estimation, positive or negative, compared to the control: -3 = high negative; -2 = medium negative; -1 = low negative; 0 = null; +1 = low positive; +2 = medium positive; +3 = high positive

Selected area	Crops[††]	BL	SL	CRA	CRC	L	AgU	SOM	PDI	TF	NT	GI	SA
Egypt	FC	–	–	–	–	–	–	–	–	–	–	–	–
Morocco	FC	–	–	–	–	+3	–	–	–	+2	+2	0	+2
Spain	TC	0	0	0	0	0	0	0	0	+1	+1	0	+3
Spain	TC	0	0	0	0	0	0	0	0	+1	+1	0	+3
Spain	TC	0	0	0	0	0	0	0	0	+1	+1	0	+3
Syria	FC	–	–	–	–	+3	–	–	–	+3	+2	0	+3
Turkey	FC	0	+1	0	0	+2	–	–	+2	+3	+3	–	+2

[†]BL: biodiversity loss; SL: soil loss; CRA: crop residue amount; CRC: crop residue cover; L: leaching; AgU: agrochemical use; SOM: soil organic matter; PDI: pest and disease impact; TF: technical feasibility; NT: need for training; GI: gender impact; SA: social acceptance.
[††]FC: field crops (winter cereals, chickpeas, legumes); TC: tree crops (olive, almond and vineyard).

Reasons to disregard the use of the technology are: no availability of water, high investment; cost of labour; and lack of stability.

Conclusions

Improvement

(i) With supplementary irrigation, the risk of erratic and climatic conditions is minimised. Water is saved and in some cases more efficient use of this water for yield production is obtained.

(ii) Higher economic margin is an important advantage and also stability is increased.

(iii) When drip and sprinkler irrigation are used, less soil evaporation improves water use efficiency, and there are less soil losses.

Disadvantages/limits

(i) Increasing chemical fertilisers, weed control, tillage and natural degradation of plant cover. Drip irrigation systems are more costly than sprinkler irrigation. Less protein content in winter cereals.

(ii) Main limitations are that water resources for irrigation must be available, and farmers should be discouraged from over-irrigation.

Conditions of use

(i) Source of water is needed and irrigation facilities should be installed.

(ii) To be more efficient, technology needs to be coupled with more efficient irrigation techniques, and the development stage of the crop should be well mastered. Farmers must be able to purchase a system. Tensiometers or other measurements for soil water contents should be used. This practice should be completed with the correct amount of N use as well as seed rates with new varieties.

Recommendations

(i) When using this technology, additional equipment showing soil water and water measuring devices should be used. Drip irrigation system is suitable for small holding farms less than 2 ha. Drip irrigation could be used to diversify crop production.

Application of N can increase WUE for grain yield and total dry matter. New varieties developed for irrigation conditions should be tested for supplemental irrigation.

Summary. Integration of technologies

At research level the technologies that have been tested have a high degree of heterogeneity. Experiments in conservation tillage systems have been conducted in half the selected areas, mainly for field crops such as winter cereals. However, some data from conservation tillage experiments in Italy have been described and analysed for orchard crops. Supplementary irrigation and water harvesting have been tested in a smaller number of areas because they are more specific for orchard crops such as olive, almond, etc., that are grown less than winter cereals. Despite this general tendency, some references on the use of supplementary irrigation and water harvesting for field crops have been mentioned (i.e. Egypt).

In general, the evaluation of these technologies has demonstrated the increase of yield, enhanced by the utilisation of the alternative systems proposed compared with the traditional ones. Yield stability and quality have been improved to a much lesser degree. Not many other aspects of the technology, other than yield, have been quantitatively evaluated. Data of water use and water use efficiency from the experiments are scarce. When measured, they were positively improved, especially with the use of conservation tillage. Environmental aspects are strongly considered by researchers and agriculturalists in the areas but seldom quantified. Alternative systems of the evaluated technology improved the environmental aspects, but negative considerations have to be taken into account when more water is moving into the system and leaching can be promoted. Sometimes more availability of water supposes more biomass production and more fertilisers and pesticides are required. Researchers and advisers, aware of this situation, alert about negative impact in long-term sustainability.

Acceptance of the alternative technology is related to the age, education and income levels and farm size of the farmer. Younger farmers with medium to high educational levels and higher levels of incomes in larger farms are clearly the most receptive to the adoption of these new technologies.

In all cases, users of these technologies admitted the benefit and the positive impact on the community, although more input and investment are needed.

It is significant to note the high incidence of Extension Services in development, training and advice for technology transfer. In most of the areas they have been recognised as the promoters and supporters of technological change for these technologies. Researchers are also well accepted by farmers; however, surprisingly, private industries are not mentioned. In fact, many handicaps to the development of technologies come from the lack of materials and spare parts to support and maintain the technique.

Not much integration between these technologies has been recorded. In some areas multi-factorial experiments have been recorded that take into account two or in very few cases three technologies such as tillage and fertilisation to explore the interaction. However a holistic strategy with several technologies has not been planned anywhere. This is a negative aspect to be considered from this holistic point of view. An example could be described as follows: water harvesting can be the first step to obtain extra water to be applied in a programme of supplementary irrigation. Moreover conservation tillage systems for soil and crop management can be very useful to make more efficient use of this water avoiding evaporation from the soil and promoting transpiration through the plant. For this reason programmes and projects based on integrated experiences could help much more to release optimal recommendations for these areas.

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