Research and technology transfer in effective water use in morocco : a review

M. Karrou[1]

[1] Department of agronomy, Inra, BP 589, Settat Morocco

Abstract

Crop production in rainfed areas of Morocco is frequently affected by water shortage and high fluctuations of rainfall. To reduce the effect of this environment stress and compensate yields reduction due to drought, the government of Morocco has opted for the development of irrigation in some areas. In fact, to make a better use of rivers water, Morocco has invested in dams construction. Consequently, regional extension services (Offices régionaux de mise en valeur agricole, Ormvas) were created to advise farmers and to ensure a good distribution of water. Nevertheless and unless sound irrigation techniques are mastered and used by farmers, the government investment will not have a substantial impact on the development of Moroccan agriculture and hence water losses will remain high. The objective of this paper is to review research and technology transfer achievements in irrigation water use and to analyze the present situation and perspectives. Research data showed that Blaney Criddle, the mostly used method for estimating potential evapotranspiration (ETO) in Morocco, has to be improved by introducing a correction factor in the equation or changed by more accurate and adapted methods such as Penman Monteith or Priestly Taylor. Maximum evaportranspiration (ETM) and crop coefficients (Kc) have been determined for different crops. Surface irrigation technique has been improved by introducing the rotative laser for soil surface levelling and by adapting surge irrigation. Methods and indicators of irrigation scheduling such as water balance technique, canopy temperature and other plant indicators, have been tested. Critical stages for supplemental irrigation of wheat were identified. Two (at tillering and heading) to three (at tillering, heading and grain filling) irrigations during the growing season are enough to increase substantially and sustain wheat yields. The potential possibility of using nonconventional water and the role of agroecological characterization in Agriculture have been proven. We can conclude from this investigation that, although a substantial amount of on-station research information exists, the adoption of developed technologies is still lacking at the farm level. Consequently, in regions where the technology was already developed, a more adapted and efficient system of technology transfer has to be used. In other areas, a research program has to be developed. In this paper, recommendations for more oriented research / extension program were made.

Key words : Research, extension, farm, irrigation, management, environment, evapotranspiration

Résumé

Recherche et transfert de technologie sur l'utilisation efficiente de l'eau : revue bibliographique

La production végétale en agriculture pluviale est fréquemment affectée, au Maroc, par le manque d'eau et les fortes fluctuations de la pluviométrie. Pour réduire l'effet de ce stress environnemental et compenser la réduction des rendements due à la sécheresse, le gouvernement marocain a opté pour le développement de l'irrigation dans certaines régions du pays. En effet et pour tirer plus de profit des eaux des rivières, le Maroc a investi dans la construction des barrages. Par conséquent, les Offices régionaux de mise en valeur agricole (Ormvas) ont été créés pour conseiller les agriculteurs et assurer une bonne distribution de l'eau. Néanmoins, l'investissement fait par le gouvernement ne pourrait avoir un impact substantiel sur le développement de l'agriculture marocaine et réduire les gaspillages d'eau que si des techniques d'irrigation plus performantes et plus adaptées sont maîtrisées et pratiquées par les agriculteurs. L'objectif de ce papier est la mise au point sur les acquis de recherche et de transfert de technologies dans le domaine de l'utilisation de l'eau d'irrigation et l'analyse de la situation actuelle et les perspectives. Les résultats de recherche obtenus ont montré que Blaney Criddle, la méthode d'estimation de l'évapotranspiration potentielle la plus utilisée au Maroc, doit être améliorée par l'introduction dans l'équation d'un coefficient correctif ou changée par d'autres méthodes plus précises et adaptées telles que Penmann Monteith ou Priestly Taylor. Les évapotranspirations maximales (ETM) et les coefficients culturaux (Kc) ont été également déterminés pour différentes cultures. L'irrigation gravitaire a été améliorée par l'utilisation du laser rotatif qui facilite le nivellement des parcelles et par l'adaptation de la méthode, connue sous le nom d'irrigation par vagues (surge irrigation). L'information existante montre l'intérêt de la mesure du bilan hydrique, de la température du couvert végétal et d'autres indicateurs liés à la plante dans le raisonnement des périodes et pilotage des irrigations. De même les stades critiques d'irrigation du blé ont été identifiés. En effet deux (au tallage et à l'épiaison) ou trois (au tallage, épiaison et au grossissement du grain) apports d'irrigation d'appoint au cours du cycle de développement sont suffisants pour assurer une augmentation substantielle et une stabilité des rendements. L'utilisation potentielle des eaux usées et le rôle de la caractérisation agro-écologique dans le développement de l'Agriculture ont été démontrés. De cette investigation, on peut conclure que même si beaucoup de résultats de recherche en station existent, les technologies développées ne sont pas encore utilisées au niveau de la parcelle de l'agriculteur. Par conséquent, dans les régions pour lesquelles la technologie existe, un système de transfert de technologies plus adapté et plus efficient doit être utilisé. Dans d'autres régions un programme de recherche doit être développé. Dans ce papier des recommandations pour un programme de recherche/transfert de technologies plus orienté ont été faites.

Mots-clés : Technologie, transfert, parcelle, eau, irrigation, techniques, évapotranspiration, pilotage

ملخص

البحث ونقل التكنلوجيا في ميدان الإستخدام الجيد للماء : دراسة مرجعية

م. قرو
قسم الزراعة، المعهد الوطني للبحث الزراعي، ص.ب. 589 ، سطات، المغرب

تتأثر الزراعة البورية بالمغرب فى غالب الأحيان بقلة الماء و تدبدب كبير فى تساقطات المطر. للتقليص من فعاليات هذا الضغط اللاحيوى ورفع الإنتاج اختارت الحكومة المغربية تنمية الري فى بعض المناطق. ولأجل الإستفادة من مياه الأنهار، قام المغرب بالإنفاق بشكل كبير فى بناء السدود، و لهذا خلقت المكاتب الجهوية للإستثمار الفلاحى لإرشاد الفلاحين وتأمين توزيع عقلانيبينهم للماء. لكن لا يمكن للمصاريف التى قامت بها الدولة أن يكون لها مفعول كبير على مردودية الزراعة المغربية إلا إذا استنبطت و استعملت من طرف الفلاحين تقنيات الري الناجعة و الملائمة. الهدف من هذا المنشور هو مراجعة نتائج البحث و نقل التكنولوجيا المتعلقة باستعمال ماء الري وتحليل الوضعية ا لراهنة و المستقبلية. بينت النتائج المحصل عليها أنه يجب تحسين كيفية تقدير تبخر الماء (ETO) المستعملة عموما بالمغرب، أي طريقة (بلاني كريدل = Blaney Griddle) بإدخال عامل تصحيحي (Coefficient correctif) أو استعمال كيفيات أخرى أحسن وملائمة مثل "بنمان منتي (Penmann Monteith) أو "بريسلي تيلور" (priestly taylor). لقد حصل كذلك على مقادير تبخر أنواع المحصولات (ETM) و عوامل نباتية (Coefficients culturaux) إن تقنية الري السطحي (Irrigation gravitaire) قد تحسنت بإدخال عملية تسوية سطح الأرض بأشعة الليزر (laser) و تقنية الري "الموجي" (Irrigation par vagues) . لقد بينت النتائج كذلك أن قياس رطوبة الأرض وحرارة النباتات وعوامل أخرى تتعلق بالنبات يمكن أن يساعد على معرفة أوقات الري وكمية الماء التي يجب السقي بها. هذا من جهة، و من جهة أخرى فإن مواعد السقي التكميلي بالنسبة للقمح شخصت ولهذا فسقيتين (غداة التفريخ و خروج السنبلة) أو ثلاثة (غداة التفريخ، خروج السنبلة و ملأ الحب) كافية لضمان زيادة ملموسة فى الإنتاج و استقراره. إن مساهمة استعمال الماء غير التقليدي (eau usée) و معرفة البيئة البيو طبيعية (caractérisation écologique) في التنمية الزراعية قد حللت. في الخلاصة يمكن القول بأن مهما أن عديد من نتائج البحث فى محطات التجارب موجودة فإن هذه النتائج لا زالت لم تنقل إلى الحقل ولم تطبق من طرف الفلاح. لهذا يجب وضع برنامج ملائم و فعال فى ميدان نقل التكنولوجيا في المناطق التي تتوفر على نتائج البحث. في مناطق أخرى من اللازم وضع برنامج متكامل في البحث و نقل التكنولوجيا. في هذا العرض قدمنا توصيات في مجالات البحث و نقل التكنولوجية.

الكلمات المفتاحية : تكنولوجيا، نقل، الماء، السقي، التقنيات، تبخر الماء، نموذجية

Introduction

The most limiting factor of crop production in Morocco is the water shortage and high fluctuations of rainfall. Drought in most regions of the country can occur at any time. Consequently, it is very difficult to predict yields and management of crops under these situations. The effect of water deficit is accentuated by heat stress that occurs usually during late spring and early summer. Furthermore, in semi-arid and arid areas, soil depth is another limiting factor. In fact, many soils are shallow and have low water storage capacity.

In irrigated zones production is often affected by low irrigation water availability and inadequate irrigation management at the farm level.

All these factors contribute to low soil water availability and inefficient water use of crops.

In addition to the effect of the environment variability on production, high population growth rate and change in life style of moroccans has increased the demand for food and other needs.

Because of these problems, the government has opted for the development of irrigation. In fact the project of irrigating one million hectares (ha) by the year 2020 has been a high priority for Morocco. The objective of irrigation development is not only to reduce the effects of the environment on productions and to ensure food supply, but also to make the irrigated zones play their role in the economy of the country as a whole.

Despite the efforts undertaken to solve agricultural production problems, water shortage remains a problem in Morocco and this natural resource cannot anymore meet rural, urban and agricultural needs. The average area that can be irrigated is around only 1.35 million ha (Mamva 1994). Under these circumstances, water has to be used more efficiently. To ensure this efficiency, a good management of irrigation is an issue and requires participation of the farmer, the extension specialist, the researcher and the decision-maker. The objective of this paper is to review research activities and results on soil-water-crop relationships in Morocco, describe and analyze the system of water distribution and irrigation management by extension services and recommend more oriented research and extension actions for a better use of water at the farm level.

Research studies on soil-water-crop relationships

Studies on soil-water-crops relationships in Morocco concerned rainfed and irrigated areas. A lot of work on water management of rainfed agriculture has been published. During the conference on dryland agriculture held in Rabat (Morocco) from may 24 to may 27 1994, some of this work was presented. It was shown (Karrou and El Mourid 1994) that conservation practices (fallow, minimum and no till, water harvesting...) and rational use of limited amount of water (adapted varieties and species, weed control, supplementary irrigation...) are means that can help increase and stabilize crop production in semi-arid areas.

In the case of irrigated agriculture, it is very difficult to give an inventory of all research works that have been conducted on soil-water-crop relationships. However, the main research issues on crop water requirements and management and on the environment issues will be addressed.

Crop water requirements and scheduling

The objectives of research conducted in irrigated areas of Morocco are to quantify water requirements of different crops during their growth and development stages and to better manage irrigation (scheduling and amounts).

Understanding water-soil-crop relationships is a very important concept because the level of a crop production is a function of the actual evapotranspiration (ETC) that depends on soil moisture regime and the maximum evapotranspiration (ETM). Since ETM for a crop corresponds to the maximum of water that can be used under non limiting soil moisture conditions, this parameter is usually considered as water requirement of this crop. We say then that there is a need for irrigation when water supply through rainfall or soil moisture storage is less than ETM.

Maximum evapotranspiration for a crop is determined directly in the field or in lysimeters (water balance method). It can also be calculated if agroclimatic parameters are known (modeling methods). In this case ETM =(Kc)*(ET0), where Kc is called cultural coefficient and ET0 corresponds to reference evapotranspiration.

Because it is simple and requires only temperature, Blaney Criddle is the method that has been used for many years to estimate ETM in different irrigated regions of Morocco (Anafid 1990). Meanwhile, and in order to better estimate water requirements of crops, other methods are under investigation. In fact many lysimeters have been built in different areas (Ouled Gnaou in Tadla, Taroudant in Souss Massa, Zagora, Gharb, Ouarzazate etc.) and ETMs (for many crops) and ET0 have been determined. Crops concerned by these investigations are bread wheat, sugar beet and alfalfa in Tadla; orange trees in Taroudant; cereals, alfalfa and palm trees in Zagora and sugar cane in the Gharb (Der 1988).

A lot of on-station information on ETM exists (Der, since 1983). However it is not yet used at the farm level in irrigation management. Moreover, to improve water use efficiency, experiments on deficit irrigation have been conducted to evaluate how application of fractions of ETM can affect crop production.

Since ET0 is required for the determination of Kcs for crops, a research program on this parameter has been undertaken in different areas where lysimeters are located. At the same time different methods of ET0 calculations (based on meteorological parameters) have been compared to ET0 measured (lysimeters) in order to identify those adapted to different environments of Morocco. In fact Blaney Criddle, modified Penman (Fao 1976) and class A pan methods are studied (El Hammouri and Handoufe 1994). These authors found that for Ouarzazate region Blaney Criddle, compared to the other two methods that were similar in precision, underestimated ET0 and they proposed the introduction, in the Blaney Criddle formula, of a correction factor called Kcor. Zeggaf (1994) compared nine methods of ET0 estimation, using Ouled Gnaou data. He showed however, that

Blaney Criddle formula underestimates this parameter and that Penman Monteith and Priestly Taylor methods are more accurate.

Different methods or indicators of irrigation scheduling are available. Some are based on soil water balance (using neutron probes for example) and others take into account the physiology of plants and their response to water stress. The plant indicators are leaf rolling, leaf water potential (pressure bomb or psychrometer), leaf diffusive resistance (porometer), canopy temperature (infra red thermometer) etc.. Soil water balance and canopy temperature are the indicators that have been tried in irrigation scheduling in Morocco and gave good results. Spatial tele-detection of canopy temperature is an efficient way of planning irrigation. However, it is expensive (Belabbes 1994).

Irrigation methods

Surface irrigation : It is the most used method in Morocco. Since it is the technique that the farmers prefer, it has been improved to be more efficient (Ait Kadi 1994). Some of these improvements are the use of the rotative laser for smoothing the surface of the area to be irrigated, the reduction of the volume of water at the source when water is close to the end of the furrow (surge irrigation). These changes make irrigation more homogeneous and reduce water losses by percolation.

Sprinkler irrigation : Because it was expensive (requires a lot of energy), sprinkler irrigation was not successful when it was first introduced in Morocco. However, with the modification of the system (low pressure sprayers, mechanized equipment) this method, through the pivot irrigation, has been accepted and adopted by farmers in semi-arid areas of Morocco.

Micro-irrigation : In micro-irrigation water is applied just to small units of field area. Consequently, water is used more efficiently and losses are avoided. Results showed that this method is more efficient when crops are irrigated at night. In Morocco, more progress has been made in conception and fabrication of more efficient system of micro-irrigation.

Supplementary irrigation

Since water (precipitations, irrigation) has become scarce and cannot meet the increasing demand of Morocco, this natural resource has to be used more efficiently. Consequently, water needs to be supplied only at critical stages of plants. This water management technique is called supplementary irrigation. The objectives of research on supplementary irrigation conducted in Morocco are to increase and stabilize wheat yields in the rainfed areas and to increase yields and water use efficiency in irrigated perimeters by applying water less frequently.

Different institutions have been interested in this research area. Studies coordinated by Der (Directorate of Rural Equipment) concerned in the first phase Tadla (Ouled Gnaou) and then Souss Massa and aimed the determination of critical stages. In the second phase this study was extended to Moulouya, Doukkala, Settat and Meknès. Other cultural practices (seeding rate, nitrogen rates, tillage methods) were investigated under supplementary irrigation. Results from Ouled Gnaou (Handoufe *et al.* 1987) showed that the optimum periods for irrigation are planting, heading and grain filling. However, more information on

the other cultural practices under supplementary irrigation is needed before making any conclusion (Handoufe *et al.* 1992). Research conducted by Inra (National Institute of Agronomic Research) in Settat region (Boutfirass *et al.* 1994) and by Iav HII (Hassan II Agronomic and veterinary institute) in Meknès area (Lahlou *et al.* 1992; Bazza and Laroussi 1994) showed however, the advantage of irrigation at tillering and at heading. Results obtained by the Aridoculture Center in Settat were confirmed (Lamine *et al.* 1993) using SIMTAG model (growth and development model). Fao Model (Cropwat) tried in Tadla, predicted too many periods of irrigation (5 to 6) and seemed to be less accurate (Chati 1994).

Environment and irrigation

Salty and waste water

In order to reduce the effect of salt on crop production in some areas and to investigate the possibility of using salty and waste water in irrigation, many scientists have been interested in the effect of this water on growth, development and physiology of crops.

In the case of salt, differences in performance among crops have been found with barley and tomato being the most tolerant. Tolerant varieties have been identified (Faiçal and Amri 1994). Moreover the role of ions exchange, proline, photosynthesis, betaine and osmotic adjustment has been verified (Faiçal and Amri 1994; Kabil and Karrou 1994 and El Iklil and Karrou 1994). Many of these studies have been conducted in controlled environments (green houses). Examples of investigations on salt in the field are those undertaken by Inra on barley and by Der on different crops in Ouarzazate. This latter experiment showed that alfalfa tolerate more salt than cucumber and peas (El Hammouri and Handoufe 1994).

For waste water, the main objectives of studies in Ouarzazate are to see how purified waste water affects the biological quality of productions, and the environment. Results obtained are promising (El Hammouri and Handoufe 1994). However, more studies are needed.

Agro-ecological characterization

Recently, scientists have become aware of the importance of the agro-ecological characterization and its role in orienting research and technology transfer programs. The experience of Inra in collaboration with DMN (National Meteorological Directorate) and Icarda showed that valuable information can be obtained through this characterization. Using Geographical Information System (GIS), Spatial Weather Generators and growth models, spatial mapping of soil types, frequencies of rainfall and probabilities of early and late droughts occurrence were obtained. Moreover, supplementary irrigation scheduling was predicted. Combining soil and climate information, vegetative growth periods were calculated. The study interested only a small area (Test zone) of semi-arid and arid regions of Morocco (Göbel 1994). It will be extended in the future to other conditions including irrigated perimeters.

Description of large scale irrigation program

To better know how irrigation is planned and programmed, the diagram explaining the procedure of irrigation in Tadla is presented and discussed below. This diagram shows that the process of water distribution follows different steps. Prediction plan of irrigation is established in September and approved by the technical committee in October of each year before the growing season of crops starts. The original plan takes into account the predicted occupation of soil by crops or crops plan (Plan de cultures) and available water storage on September 1. Knowing the crops and the area projected for each crop, monthly water requirements of these crops are calculated. Blaney Criddle is the method that is usually used to predict these crops needs. The cultural coefficients used in this prediction are those determined for Fall and Spring periods (Anafid 1990). At the same time, predicted monthly water supply for irrigation is calculated taking into account the amount of water stored on the first of September and water requirements for industry. The original "Plan de cultures" is then readjusted taking into account the confrontation of projected monthly crop requirements and water supplies. The monthly and annually water allocation program and the "Plan de cultures" are then approved by the technical committee in October taking into account the expected water storage (it takes into account weather prediction). During the growing season this irrigation plan is modified according to the progress of water supply in time, water savings and precipitations regime. Water allocation during the growing season is usually based on the "Plan de cultures" and water demand submitted by farmers. The extension agents adjust this demand according to water availability. When there is water shortage a ten hours/hectare of irrigation is usually a rule of thumb.

Analysis of the large scale irrigation and recommendations

According to the diagram described above, we can see that there is a competition between agriculture and industry sectors, for water and that irrigation management is influenced more by water availability than by crop water requirements. Water requirements of crops can be fully met only when water is not a limiting factor. However, because of drought that occurs frequently in Morocco and high demand for water (high competition between agriculture and industry, urban and rural needs..) irrigation management has become very difficult. In fact restrictions on water have been made and production of certain crops have been affected.

Irrigation management in large irrigated perimeters of Morocco is based on a method that takes into account the total water availability and requirements of crops in the whole area. Management of water at the regional level is well thought. In fact water requirements are estimated scientifically (although Blaney Criddle is an empirical method) and the extension specialists in charge of this estimation have some background in irrigation management. Management at the farm level needs however to be improved.

Blaney Criddle, the method that is used almost everywhere in Morocco, takes only temperature into account. It may not be adapted to different situations of Morocco. In fact, it was shown earlier that it can overestimate or underestimate

ETO in different areas. Since in some regions information on climatic parameters and on ETO is available, it is important either to identify more accurate methods (Penman and Priestly Taylor 1 were proved adapted to some regions) or to readjust Blaney Criddle. This will ensure better predictions of water requirement at the regional level and more efficient irrigation management at the farm level for each crop. Instead of using monthly Kc, these coefficients have to be determined for each crop and for different development stages and especially the critical ones. This will help save water and improve water use efficiency.

The program of irrigation proposed by farmers may not be adequate. Some farmers do not know how to manage irrigation. Others overestimate their needs to have extra water for other crops. Moreover, a ten hours/ha of irrigation is not based on crop requirements. Some crops need more water than others. Because of these problems, irrigation at the farm level is not well managed. In fact by comparing irrigation management of wheat by farmers in Ouled Gnaou area to management based on research results and calculated water requirements in the case of supplementary irrigation project, it was shown (Chati 1994) that farmers do not know well which growth stages of wheat are more sensitive to water shortage. Moreover, the farmers think that the higher the amount of water is applied, the higher is the grain yield. Consequently, they over irrigate their crop when they have access to enough water.

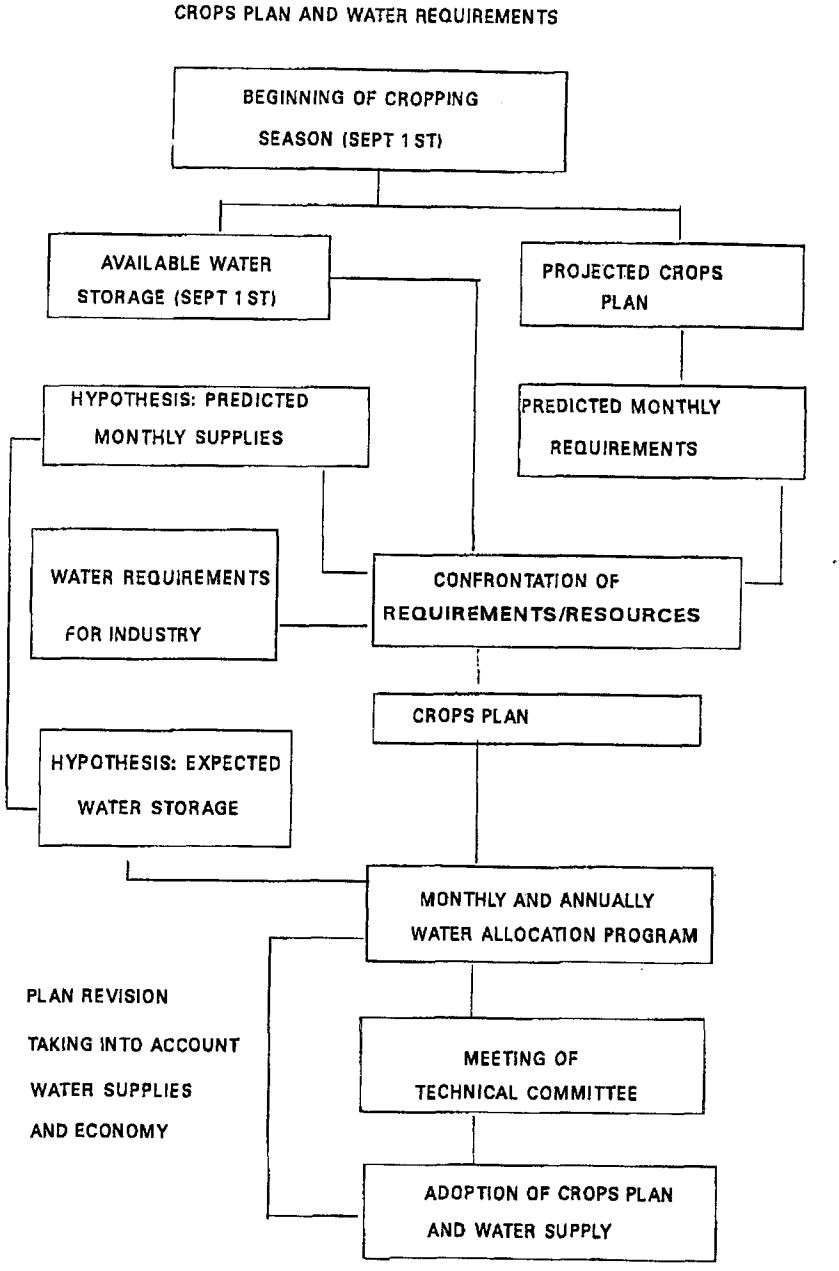
To increase crop water use efficiency and production and save water, losses between farm gates and crops plots have to be reduced and improved techniques of irrigation (modified surface irrigation, micro-irrigation) have to be introduced at the farm level. Sensitive stages of crop development have to be identified and water requirements at these stages have to be estimated. Moreover, research on deficit irrigation has to be extended to other regions. At the same time more water efficient and drought tolerant varieties need to be developed. Improved and adapted crops and soil managements, like tillage, fertilizer applications, plant populations, have to be identified and used by farmers in order to take advantage from irrigation. Some data is available as mentioned before, but more research is needed.

In addition to training of extension agents and farmers, more efficient ways of water management at the regional and farm levels are needed. This requires agro-ecological characterization and modeling. In fact more data base on climate, soil and crops need to be collected and analyzed using GIS (spatial mapping). This information can also be used to calibrate and validate models. These models can help in crops water requirements estimation and water balance evaluation. These tools (models) are means that can facilitate irrigation management and decision making.

Information dissemination, on-farm demonstrations and training of extension agents and farmers are very important for the transfer of new technologies in water management. This component is neglected except in the case of supplementary irrigation of wheat for which a short training was offered for extension agents and on-farm demonstration trial was conducted.

Finally the impact and socio-economical aspects of irrigation has to be investigated.

IRRIGATION PROGRAMMING IN TADLA



Conclusion

In conclusion, I can say that a lot of information on crops water requirements and irrigation techniques and management exists, but only part of it is known to extension agents. If all this information reaches the farmer and if models are used, irrigation will make more impact on Moroccan production. Nevertheless, research need to be continued and extended to other aspects and regions and more collaboration between researchers, extension specialists and farmers have to be consolidated.

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