Assessment of Drip Irrigation in Morocco

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Abstract

Faced with chronic water shortages, the government of Morocco put forth an ambitious plan to equip 700,000 ha or 50% of the total irrigated land in Morocco with drip irrigation by the year 2022. Most of this acreage would be achieved by converting from inefficient flood irrigation methods to drip irrigation. The main tool used to encourage growers to adopt drip irrigation is a government subsidy that covers 60% of the total initial investment cost. Approximately 163,000 ha were equipped with drip irrigation at the end of 2008. Most of this acreage belonged to medium or large land owners and most of it was in horticultural crops, particularly fruit trees. Smaller farmers were less likely to convert to drip irrigation due to its high investment cost, the difficulty to obtain loans (the subsidy money is not disbursed until after project completion), or non-familiarity with drip irrigation. Other constraints include illiteracy, type of crops grown, and the subsidy approval process, which was lengthy and cumbersome. In order to reach its target, the government plans to convert large blocks of land to drip irrigation. It will build the infrastructure to bring pressurized and filtered water to the farms but each farmer will be responsible to equip his/her land with drip irrigation and receive the 60% subsidy. Additional incentives (e.g., greater subsidy, trust funds to guarantee loans to small farmers, etc.) may be needed to convince farmers (mostly small land holders) to sign on the program. Many are not convinced that drip irrigation would work or be profitable for crops such as wheat, barley, or alfalfa. All the drip irrigation installations I visited were surface drip irrigation systems whereby driplines were laid on the soil surface, which may interfere with field operations. Most were designed and installed by consultants or irrigation companies with little grower's participation. The average cost of a drip irrigation system in the plain of Tadla was $5,737/ha and varied with farm size, crops grown, and degree of sophistication. Approximately 70% of the farms equipped with drip irrigation had a water storage reservoir. Water reservoirs allow growers to store their surface water allocation, which they receive every two to four weeks and thus be able to use it on a more frequent basis with their drip system. Even growers who only have access to ground water (most use both surface and ground water to meet crop demand) build water reservoirs to add flexibility to their operation and qualify for the maximum subsidy amount. There is the concern that the development of drip irrigation on a large scale would further deplete ground water, which has been used extensively in the last 20 years to supplement surface water.

Drip irrigation is not a panacea but may be the best hope to conserve irrigation water in Morocco and maintain or enhance agricultural productivity (produce more with less water). It may not be feasible for every situation; therefore efforts to improve existing irrigation methods should be pursed. Moreover, Morocco should step up research and outreach programs to assist growers and consultants design and manage drip irrigation systems adapted to the social, economic, and agro-climatic conditions in the country.

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Introduction

Morocco has a Mediterranean-type semi-arid to arid climate with large fluctuations in precipitation amounts. It has experienced frequent droughts, which, along with aging infrastructure, rapid population growth, and the expansion of its economic and industrial base has led to water shortages, some severe. For example, in 2000-2006 only 55 to 60% (on average) of the demand for irrigation water was met from the main storage reservoirs (MADRPM-1, 2008). Still, there is the perception that agriculture “wastes” water since approximately 81% of the total irrigated acreage in flood-irrigated (Table 1) using traditional methods such as the “Robta” (Fig. 1 & 2), which involves furrow flooding over a series of small basins (TRM, 1999). It is estimated that with the Robta, only about half of the water that enters the field is used by the crop. The other half is “lost” mostly through deep percolation below the root zone. An additional 15 to 20% of the water is lost during transit from the dam to the field. Several methods to increase flood-irrigation efficiency have been introduced but their adoption by farmers remains low due to factors such as the relatively high cost of land leveling.

Table 1: Lands equipped for irrigation in Morocco

Irrigation Category*	Irrigation Type (ha)			Total (ha)
	Surface¶	**Sprinkler**	**Drip**	
‘Grande Hydraulique’ (GH)	533,900	113,800	34,900	682,600
‘Petite et Moyenne Hydraulique’ (PMH)	327,200	6,900	-	334,100
‘Irrigation Privée’ (IP)	317,600	16,950	106,900	441,450
Total	**1,178,700**	**137,650**	**141,800**	**1,458,150**
%	81	9	10	100

Source: PNEEI (2007)

¶Surface irrigation usually refers to flood- or furrow irrigation.

*GH refers to large irrigation projects and PMH to medium and small irrigation projects built by the government. IP refers to private irrigation outside the government-sponsored projects.

Figure 1. Furrow irrigation in the plain of Tadla

Figure 2. Typical Robta basins

In 2007, the government issued an ambitious plan ('Plan National de l'Economie d'Eau d'Irrigation' or PNEEI) to conserve in excess of 510 million cubic meters of irrigation water per year (MADRPM-2, 2007). The main premise of PNEEI is that past and current measures to conserve water in agriculture such as the revamping of existing irrigation infrastructure and the introduction of improved irrigation methods (e.g., sprinkler irrigation) are not sufficient to address water shortages. The goal of PNEEI is to equip approximately 555,000 ha of irrigated land with drip irrigation[2] from 2008 through 2022 (Table 2). Most of this acreage would be achieved by converting land that is currently irrigated with traditional methods such as the Robta to drip irrigation. At the end of 2008, approximately 163,000 ha were drip-irrigated, mostly in the 'IP' zones, which would bring the total acreage equipped with drip irrigation to 700,000 ha by 2022. PNEEI predicts water savings of 20 to 50% and crop yield gains of 10 to 100% compared to other irrigation methods.

Table 2. Land to be converted to drip irrigation from 2008 to 2022[3].

Irrigation zone/type	Total irrigated land (ha)	Land (ha) to be converted--	% of Tot

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2

The exact term used in PNEEI is 'irrigation localisée', which could encompass other forms of micro-irrigation but appears to refer mainly to drip irrigation.

3

Differences in irrigated acreage between Tables 1 and 2 may be due to the fact that not all the land equipped for irrigation is actually irrigated plus some irrigation projects may have been abandoned, scaled down, or not yet completed.

					al irrigated land
		Collectively	Individually	Total	
PIT	109000	49040	39700	88740	81
Total GH	670430	217940	177150	395090	59
Private irrigation	441400	0	160000	160000	36
Grand total	1111830	217940	337150	555090	50

Source: PNEEI (2007)

Eighty one percent of the total estimated cost of PNEEI of approximately $4.6 billion (One US $ = 8.0 Moroccan Dirhams) would be financed by the government, mostly through subsidies (Belghiti, 2005). Subsidies were increased from 30% of the cost of some (early subsidies) or all drip irrigation equipment and installation (plus the excavation of wells) in July 1986 to 60% in October 2006. Landowners who do not meet certain conditions may only receive the 30% (40% in dry regions) subsidy plus, since 1999, a bonus of $250 for each hectare of land equipped with drip irrigation (Belghiti, 2005; MADRPM-3, 2008). Payments at the 60% rate cannot exceed $4500/ha if a water storage reservoir is built and $2750/ha if it is not. Additional subsidies are provided for farm equipment, improved seeds and tree seedlings, etc. The procedure for applying for and obtaining government subsidies has been simplified and streamlined.

To a non-specialist, the goal set by PNEEI to equip half of the irrigated land with drip irrigation is daunting but Morocco has a long history of developing and managing large-scale irrigation projects. I will discuss some of the rewards and challenges of PNEEI, particularly in the plain of Tadla.

Main features of the study area

The area I visited the most is the Tadla Irrigated Perimeter or PIT (Fig. 3), which is one of nine large-scale agricultural irrigation districts developed by the government of Morocco to enhance food production, create jobs, and store and manage water. Water is conveyed to PIT farms from two main reservoirs, Bin El Ouidane and El Hansali via approximately 3000 km of canals (Fig. 4). The total gravity-fed area is around 100,000 ha and is home to 27,000 farmers. Additional lands (≥8500 ha) are irrigated exclusively with well water outside the zone 'GH'. Surface water is allocated to blocs of land by ORMVAT ('Office Regional de Mise en Valeur Agricole de Tadla), after consultation with stakeholders, based on available supplies and the crops grown. Priority is usually given to fruit trees, sugar beets, and forage crops. However, each farmer is free to manage his allotment based on his needs. Water is delivered on a rotational basis or 'Tour d'Eau' every 2 to 4 weeks.

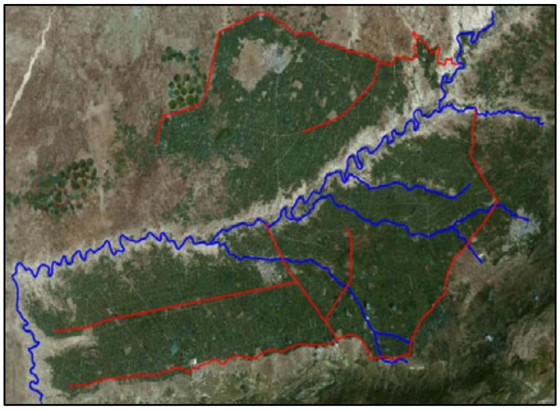

Figure 3. Satellite view of PIT composed of two main irrigation zones, Beni Moussa and Beni Amir. Source: ABHOER.

Figure 4. Raised irrigation canal at PIT. Source: ORMVAT

Annual natural precipitation averaged 268 mm from 1970 through 2007 with a downward trend (Fig. 5). Less than 50% of the water required to meet crop water demand was supplied from Bin El Ouidane or El Hansali in 1996-2008 (Fig. 6&7). The deficit is partly made up with groundwater, which has been tapped extensively in the last 20 years. Hammani and Kuper (2008) reported the existence of 8310 active and inactive wells within PIT and over 4500 wells outside the zone of action of ORMVAT. This could have serious consequences for water supply and management in the Oum er Rbia river basin.

Figure 5. Annual rainfall at PIT-Ouled Gnaou. Source: ORMVAT

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part isn't showing of the year "1991-..."

this sum is over 100%

DEFICIT of 43%!

Figure 6. Water allocation for Beni Amir from 1996 to 2008 (Source: ORMVAT)

DEFICIT of 45%!

Figure 7. Water allocation for Beni Moussa from 1996 to 2008 (Source: ORMVAT)

Accomplishments

Approximately 10,700 ha were equipped with drip irrigation at PIT from 1991 through 2008 (Fig. 8). There was a jump in drip-irrigated acreage in 2003 and in 2007 due to increases in government subsidy.

the '3' in 'Mm3' should be superscripted

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Figure 8. Cropland equipped with drip irrigation in PIT in 1991-2008. Source: ORMVAT.

Unofficial ORMVAT data (Table 3) indicate that at least 80% of the acreage approved to receive the drip irrigation subsidy from July 2002 through November 2008 was earmarked for fruit trees (mostly citrus). This makes sense for several reasons:

- Citrus fruits are among the most profitable crops (Daoudi, 2008)
- Drip irrigation is generally cheaper and easier to install and manage in orchards than for non-tree crops such as alfalfa or sugar beets, partly because it does not require as many driplines.
- Growers who install new orchards or replace old trees with new ones get a subsidy of $975/ha. This is in addition to the drip-irrigation subsidy.
- Citrus orchards generally represent medium to large acreages and often belong to well-to-do and/or progressive landowners with a greater ability to finance their land improvement projects than smaller farmers do.

Table 3. Drip-irrigation subsidy requests approved by ORMVAT from July 2002 through November 2008, sorted by crop. Source: ORMVAT.

Crop	No. requests	Total SAU ha	SAU/request ha	Investment cost* $/ha	Subsidy $/ha	Subsidy/Cost %
Roses	5	147	29	4331	1826	42
Olive	24	670	28	4962	2862	58
Pomegranate	4	36	9	4991	2153	43
Citrus	218	3958	18	5721	2907	51
Field crops	3	45	15	6082	3649	60
Vegetables	44	547	12	6387	3352	52
Other	21	374	18	6494	3829	59
Vineyard	3	15	5	12016	3550	30
Total/w. average	**322**	**5791**	**18**	**5725**	**2979**	**52**

*One US dollar = 8.0 Moroccan dirhams

Bekkar et al. (2007) reported similar results, i.e., 83% of the drip-irrigated land surveyed consisted of citrus orchards. Only 8% had vegetable crops. The average size of the completed drip irrigation projects (sample size: 21 farms) was 12.8 ha. It was 18.0 ha when averaged over all the approved subsidy requests in 2002-2008 (Table 3). Fifty two per cent of the approved requests were for projects of 10 ha or less in size but represented only 16% of the total acreage. In contrast, projects of 20 or more hectares in size represented 26% of the requests but accounted for 66% of the total acreage (Table 4).

Table 4. Drip-irrigation subsidy requests approved by ORMVAT from July 2002 through November 2008, sorted by land size. Source: ORMVAT.

Size category ha	No. requests	Total land ha	Hectares/ request	Investment cost* $/ha	Subsidy $/ha
Less than 10	169	915	5	6159	2921
10 - 19.9	71	1047	15	5578	2903
20-49.9	63	1878	30	5416	2723
Over 50	19	1951	103	5899	3293
Total/w. average	**322**	**5791**	**18**	**5725**	**2979**

*One US dollar = 8.0 Moroccan dirhams

The average estimated initial drip irrigation cost was $5,725/ha, with large variations within and between years, crops, and individual requests. The cost generally decreased as the number of hectares increased but not always. Kobry and Eliamani (2005) reported average estimated investment costs of $7,500/ha for approved drip irrigation projects of less than 5 ha, $6,750/ha for 5 to 10 ha, and around $3,950/ha for 10 ha or more. They did not distinguish between projects that had a water storage reservoir and those that did not. Daoudi (2008) reported the following initial investment costs for citrus orchards at PIT: $6,500 to $6,875/ha for orchards of 10 ha or less and around $5,000/ha for orchards greater than 10 ha in size. He estimated the net profit margin for an orchard in full production at $5,739/ha with drip irrigation compared to $3,053/ha with flood irrigation.

Examples of drip irrigation system component costs reported in subsidy requests submitted in late 2008 are shown in Table 5. They ranged from $3,733/ha to $8,837/ha. The head station and water delivery system accounted, on average, for 63% (45-65%) of the total system cost while the water storage facility represented about 20% (18-36%) of the cost.

Table 5. Estimated drip irrigation system component costs of five projects submitted to ORMVAT in 2008.

Project No.	**1¶**	**2**	**3¶**	**4**	**5**	**Cost/ha**	**% of total cost**
System component	**Estimated cost ($)**						
Head station & water delivery	92,088	82,500	148,833	18,660	514,255	**4,062**	**63%**
Storage reservoir	36,399	40,433	60,073	14,916	139,155	**1,380**	**21%**
Pumps	30,413	4,375	7,695	2,813	106,969	**722**	**11%**
Shelter for the head station	5,714	11,198	9,636	4,979	30,128	**292**	**5%**
Total cost	**164,614**	**138,505**	**226,237**	**41,367**	**790,507**	**6,457**	**100%**
Land Area (ha)	25.4	37.1	25.6	4.7	118	210.8	
Cost/ha	**6,481**	**3,733**	**8,837**	**8,801**	**6,699**		
Reservoir Capacity (m^3)	7500	7600	7200	1920	37000		
Crop	Citrus	Citrus	Sugar beets	Citrus*	Citrus**		

¶ Projects 1 & 3 were designed by the same company.
*Citrus trees and vegetable crops
**Citrus trees and sugar beets

Most of the farms I visited had all the essential components of a modern drip irrigation system such as filtration, chemigation, flowmeters, control valves, and the option to run the system automatically (Fig. 9 & 10).

Approximately 70% of the subsidy requests approved by ORMVAT from July 2002 through November 2008 had storage reservoirs of varying sizes (Unpublished data). The rest either didn't have a water reservoir or the information was missing. Storage reservoirs are recommended even when the sole source of water is groundwater. They provide a buffer in case of well pump malfunction or other unforeseen circumstances. Storage reservoirs are even more critical when surface water is the main or only source of irrigation water. This is because surface water (e.g., from Bin El Ouidane) is allocated every two weeks or longer, depending on availability, which can cause water stress even for flood-irrigated crops. With drip irrigation, water should be applied frequently (e.g., daily during peak demand) to meet crop demand.

The newer drip irrigation installations (e.g., since 2007) were likely to have a water reservoir due to the substantial subsidy (up to $4,500/ha) provided by the government. There was a significant correlation ($r^2 = 0.63$) between reservoir size and drip-irrigation acreage (Unpublished data). Sizing of the water reservoir should be done based on the number of hectares to be irrigated and surface water availability (e.g., flow rate and 'tour d'eau'). Daoudi (2008) recommended a storage capacity of 432 m^3/ha for citrus orchards in PIT based on a water allocation of 4 h/ha at 30 l/s or 6 h/ha at 20 l/s. Growers who rely heavily on surface water may want to build reservoirs with more storage capacity (≥500 m^3/ha).

All the water reservoirs I visited were lined with a polyethylene geomembrane to prevent water seepage (Fig. 9). Kobry and Eliamani (2005) reported that the cost of the geomembrane exceeded 50% (in three-quarters of the approved projects) of the total reservoir cost. Daoudi (2008) reported reservoir costs of \$3.75 to \$5.00/m^3 for citrus orchards.

Reservoirs not only provide a buffer so that crop water needs can be met on a timely manner. They also allow sediments to settle down, thus reducing water filtration requirements. This was less of a concern than algae, which given enough sun and nutrients (e.g., N and P) multiplies rapidly and can plug up screens and cause pumps to fail. The most common control method used was an algae-eating fish called 'carpe chinoise' (Chinese carp).

Figure 9. Water storage reservoir lined with a geomembrane. PIT, March 2009

Figure 10. Disk filters. PIT, March 2009

Approximately 42% of the drip irrigation subsidy requests approved in 2002-2008 at PIT listed groundwater as the sole source of water (Unpublished data). Most drip-irrigated farms/fields had access to both surface and groundwater. Only two of the farms I visited used well water sparingly, due to its high salt content. When they did, they mixed it with surface water, which was less salty.

Only one of the 17 farms I visited had flexible drip tubing, commonly referred to as drip tape in the USA. All the other farms had solid round drip tubing. None of the installations had buried drip tapes. This makes sense for tree crops such as oranges and olives because generally, the drip tubes are laid out along the tree rows and away from vehicular traffic. For less permanent and more densely planted crops such as wheat, alfalfa, or sugar beets, laying the drip tubes on the soil surface will get in the way of field operations such cultivation and harvest (Fig. 11). Thus the driplines may have to be moved to the side or rolled back every time one has to cut alfalfa for instance.

Citrus orchards usually have two driplines per tree row (one on each side of the tree), although some farmers do not install the second dripline until the trees are few years old (Fig. 12). The most common spacing between emitters was 0.75 m and the most common emitter flow rate was 3.9 l/h. Growing crops such as melons or sugar beets or even alfalfa between the citrus trees appeared to be a common practice in new orchards equipped with drip irrigation. This was done to generate income until the trees started producing marketable fruits. Dripline spacing in sugar beet fields commonly ranged from 0.8 to 1.2 m with 0.4 m between emitters and 2 l/h flow rate.

Figure 11. Hoeing of a sugar beet field fitted with drip tubes. Ouled Gnaou, December 2008

Figure 12. Drip-irrigated sugar beet in a young citrus orchard in PIT. January 2009

Intercropping may hinder tree growth, particularly when water is in short supply, but can suppress weeds and provide nutrients when used as a cover crop or green manure for example. These practices were not observed at PIT. Often, weeds are pulled from crop fields and fed to livestock or grazed anywhere they can be found (fallow ground, ditches, road sides, along irrigation canals, etc.).

Most of the drip irrigation installations I visited were designed by private companies or consultants. More often than none, the company that designed the drip system also installed it or subcontracted parts of it to other companies (turnkey projects). This could create a conflict of interest if, for example, the design company supplies its own equipment, which may not be as good or as affordable as other equipment available on the market. There did not seem to be much grower input in the project design and limited involvement in its installation. In the farms I visited, some works (e.g., trenches for the PVC pipes) and some structures such as the shelter that houses the head station or the fence around the storage reservoir were built by property owners or their hired hands.

Collective projects

Individual drip irrigation projects at PIT averaged a little over 1,000 ha/yr from 2002 through 2008 (Fig. 8). At this rate, it would take a long time to reach the goals set by PNEEI. It is believed that farmers who have taken advantage of the government subsidies are generally well-connected, well informed, and have access to capital. Moreover, most of the land converted to drip irrigation consists of citrus orchards, which represent about 10% of the total irrigated acreage at PIT[4]. In contrast, wheat, barley, alfalfa, and sugar beets occupy 69% of the irrigated acreage and are the staple crops for small farmers. Cognizant of these facts, the government plans to convert approximately 218,000 ha collectively, of which 49,000 are located at PIT (Table 2).

Collective projects or 'projets collectifs' will make it easier for small farmers to convert to drip irrigation, since the government will build the infrastructure to bring pressurized (and filtered) water to each farm. Therefore, individual farmers will not have to build storage reservoirs for example, which would lower the cost of the drip system[5]. Each farmer will be entitled to the 60% subsidy to equip his or her land with drip irrigation. Construction of collective projects is expected to start in 2011.

In a study funded by the World Bank, an area of about 20,000 ha in Beni Moussa West was identified based on the fact that the drop of elevation from the water source would generate enough pressure to operate the drip irrigation system without additional energy input. It was later narrowed down to 10,000 ha and then to approximately 3,700 ha. This area was selected for a pilot project based on the large number of wells[6], good groundwater quality, and growers' enthusiasm for the project. There were conflicting reports as to whether the pilot project will be built first before the whole area of 20,000 ha is converted to drip irrigation.

4

The irrigated acreages for the 2009/2010 season were as follows: Wheat & barley: 34,000 ha; Alfalfa: 22,000 ha; Sucre beet: 13,000 ha; Citrus trees: 9,500 ha, Olives & other fruit trees: 16,500 ha, Summer corn/maze: 12,000 ha. Source: ORMVAT

5

Apparently attempts to build storage reservoirs for groups of farmers or farmers' cooperatives have not been too successful at PIT, unlike in other irrigated perimeters such as Souss-Massa or Moulouya. However, there were plans to equip two growers' cooperatives totaling 265 ha with drip irrigation in 2008.

6

There were 287 deep wells, 467 shallow wells, and 69 intermediate wells on 3183 ha of land.

Fifty percent of the acreage in the pilot project area was made up of farms smaller than 5 ha in size and 10% of farms > 20 ha. Cropping systems were dominated by cereal (wheat and barley) crops, alfalfa, and sugar beets (Table 6). When this area is converted to drip-irrigation, it is expected that the acreage in wheat, barley, and alfalfa will decrease while that of fruit trees (citrus and olive) and vegetable crops will increase and corn silage would be the forage of choice (SCET-SCOM, Personal Communication, January 2009). The projected cropping system would preserve PIT's vocation as a major milk and sugar producer but would enhance profitability by increasing the acreage of horticultural crops.

Water requirements[7] (Table 7) were calculated using Penman-Monteith reference ET and crop coefficient estimates from FAO's Irrigation and Drainage Paper No. 56 (Allen et al., 1998).

Table 6. Current (2008) and projected crop acreage in the pilot project area.

	Current hectarage	**Projected**	
Crop	**ha**	**%**	**%**
Cereal crops	1312	32	25
Alfalfa	742	18	10
Corn silage	0	0	15
Sugar beets	667	16	18
Citrus*	317	8	15
Olives	252	6	15
Vegetable crops	152	4	10
Total (ha)	**3445**		
Cropping intensity (%)			

7

Several subsidy requests I examined based the drip irrigation system design on peak water demands of 5 mm/day for citrus trees and 7 to 8 mm/day for sugar beet.

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part isn't showing of the year "1991-..."

this sum is over 100%

*92 ha were drip-irrigated. The total drip-irrigated acreage in the pilot project area was 111 ha in 2008

Table 7. Monthly drip irrigation water requirements (at the field level) for the pilot project.

Cropping System	**Sept**	**Oct**	**Nov**	**Dec**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Total**
	Water requirement (m^3/ha)												
Current	323	143	85	14	54	142	337	514	642	509	460	431	3654
Projected	376	184	89	17	49	128	319	586	867	864	900	840	5219
Rainfall (mm)	8.2	26.8	50.9	45.2	41.5	40.8	47.9	46.3	23.7	5.4	0.9	2.8	340

The annual drip irrigation water requirement for the projected cropping system was estimated at 5219 m^3/ha at the field level and 7223 m^3/ha at the distribution reservoir, which is about the average water allocation (7163 m^3/ha) for Beni Moussa. Water savings will result from increased irrigation efficiency. Calculations were based on the following efficiencies: From Bin El

Ouidane to the distribution reservoir: 85%, open water channels: 85%, buried water pipes: 95%, field (drip irrigation): 90% (SCET-SCOM, Personal Communication, January 2009).

Before the government would start construction of the pilot project, at least 70% of farm owners/managers must sign a commitment to convert to drip irrigation within two years of completion of the infrastructure (e.g., filtration and pumping stations and water delivery system) that would bring pressurized water to their properties. The project cost was estimated at approximately $5,000/ha to bring pressurized water to each farm and another $3,750/ha to equip it with drip irrigation.

Challenges:

Getting farmers to agree to, help pay for, or manage shared irrigation structures can be a challenge. As one company representative put it,

"Farmers are individualistic and competitive by nature. They may copy a neighbor's innovation but they will fight over borders, status, and water!"

Several concerns about the pilot project in particular and collective projects in general were raised at growers' meetings. They included:

- The ability to finance drip irrigation installation at the farm level, given the large number of small farms (about 80% are < 5 ha). This is exacerbated by the fact that farmers do not receive the subsidy money until after the project is completed. Farmers were also worried about having to pay for the infrastructure to bring pressurized water to their land[8].
- Land ownership. Most farms in Morocco have multiple owners due to inheritance laws, which makes it difficult to agree on land improvements, especially if the improvements require a substantial investment.
- Farms are often made up of scattered fields of various sizes, some tiny. Only the fields located in the selected irrigation blocs will be considered for conversion to drip irrigation.
- Even though each farmer will have his/her own water intake valve, some degree of coordination may be required among farmers within each irrigation bloc.
- Farmers worried that water prices would go up as a consequence of this project, which is likely. In 2008, the water user fee at PIT was $\$0.03/m^3$. Drip-irrigation pumping costs were estimated at $\$0.06/m^3$ at the storage reservoir (located on the farm) and $\$0.10/m^3$ at the well (Daoudi, 2008). There have been attempts to structure water fees so that farmers who "waste" water are penalized but this has not been applied due to accounting difficulties, water shortages or other reasons.
- Water availability was a major topic of discussion. Would farmers who adopt drip irrigation be guaranteed a fixed/adequate water allocation? What would happen to the saved water? Would water be available at all times?

8

Agricultural producers help pay for the irrigation infrastructure and associated services provided by ORMVAs in two ways: (1) water user fees (in effect), and (2) construction fees to recover 40% of the initial investment to build the irrigation infrastructure. The latter is payable over 17 years at 6% interest with a grace period of four years.

- How would drip irrigation work for subsistence crops such as wheat and barley? Would I have to remove the drip tubes every time I need to work the field or harvest the crop? Would it cost too much?
- Potential over supply of high value crops

There were many more questions and not enough satisfactory answers. Some of the concerns stemmed from non-familiarity with the subsidy program and the lack of information about drip irrigation in the region. A number of attendees saw drip irrigation being used in citrus orchards but they were not convinced that it would work for their crops or be economically feasible. Options that were adopted or considered by the government to ease the financial burden on small farmers willing to adopt drip irrigation include:

- A fund to guarantee loans to needy farmers
- Increase in drip irrigation subsidy
- Reduction in farmers' contribution to external works

Water conservation and environmental considerations

When designed and operated properly, drip irrigation will save water compared to other irrigation systems (Table 8). Results by Bouazzama and Bahri (2007) indicate that this may not always be the case. They surveyed 23 citrus orchards in 2002 and found that the ratio of irrigation amount versus water requirement was: 0.7 to 1.5 in 39% of the orchards, 1.6 to 2.3 in 48%, and 2.6 to 2.9 in 13%. The water applied ranged from 4420 m^3 to 18610 m^3/ha (all orchards) and produced on average 3.6 kg of oranges/m^3 (4 orchards).

Table 8. Estimated water savings due to drip irrigation in PIT. Source: ORMVAT.

Crop	Flood-irrigation	Drip irrigation	Water saved
	m^3/ha		%
Citrus	12000	7200	40
Olive	5000	2700	46
Sugar beets	8000	4800	40
Vegetable crops*	12000	7000	42

*Two crops/yr

Chohin-Kuper et al. (listed by Petitguyot et al., 2005) reported that in several Mediterranean countries, the adoption of micro-irrigation decreased water consumption per unit area but not at the farm level since the "saved" water was used to irrigate more land. In PIT, there may not be much room for expanding the irrigated acreage, so the potential for water savings with drip irrigation is real (Petitguyot et al., 2005).

A serious concern is the impact drip irrigation would have on groundwater recharge and use. Indeed, an increasing number of agricultural producers use groundwater to supplement their surface water allocation. Hammani et al. (2005) estimated the number of wells in PIT at around 10,000. Groundwater use accelerated in the 1990s due to drought and generous government subsidies. Furthermore, irrigation return flows accounted for 80% of the aquifer recharge in the plain of Tadla (Hammani and Kuper, 2008). Thus, the more flood-irrigated land is converted to drip irrigation, the less water would be returned to the river and its aquifers, which could result in further groundwater depletion, increased pumping costs and could trigger more restrictions on groundwater use[9]. Conversely, increased irrigation efficiency would narrow the gap between water supply and crop water requirements and thus reduce the need for groundwater. However, current government policies (e.g., subsidies for irrigation improvement or extension which include well excavation) seem to favor property owners who have access to groundwater.

Another concern is groundwater quality given the relatively elevated salt concentrations in some areas such as the Beni Amir (ORMVAT, 2008). Drip irrigation would reduce leaching of salts to the groundwater but can result in salt accumulation in the root zone over time (Berrada, 2006). This could be alleviated by mixing groundwater with surface water which is generally not as salty as groundwater or by flushing out the salts occasionally with large water applications.

Procedure for obtaining the government subsidy

In 2002, the regional agricultural services such as ORMVAT started reviewing the subsidy requests to make sure that the drip irrigation projects were designed and installed properly. In addition, a "Guichet Unique" or clearing house was created in 2008 within each service to streamline the application procedure for all ag-related subsidies and speed up project review and approval. This was in response to customers' complaints, abuses of the subsidy system, or faulty drip irrigation design by inexperienced or unscrupulous consultants and irrigation companies. Prior to 2002, the regional agricultural credit banks (CRCA) not only provided loans and subsidy money to eligible farmers but also monitored the irrigation project execution.

Subsidy seekers generally submit two documents, one to ORMVAT (DPA outside ORMVA's jurisdiction) and the other to CRCA or to a private bank to request a loan to finance the project since the subsidy money is not disbursed until after the project is completed. After receipt of the request, Guichet Unique and other designated staff have a total of 28 days to review, approve, and monitor the irrigation project and notify CRCA of its successful completion and the amount to be disbursed to the applicant. In turn, CRCA has two days to issue a check to the subsidy recipient.

The review and approval process can be delayed due to missing or invalid information, faulty design, or other irregularities. The applicant is notified in writing of such problems and asked to address them. He/she cannot start installing the project until the subsidy request is duly approved. Growers have the option to request the subsidy after they install the drip irrigation system, in which case they are only entitled to 30% (40% in dry areas) of the system's cost plus a bonus of $250/ha. They may choose this option to avoid lengthy delays or for other reasons such as questionable land ownership or illegal use of groundwater. In the late 1990s landowners were given a grace period of three years to declare wells that were excavated before 1995 without proper authorization. Apparently many did not due to ignorance or mistrust.

Despite marked improvements, the subsidy request is still cumbersome. In my opinion, too many people are involved in the approval process and too many details/documents are required, which makes it difficult for the average farmer (often illiterate) to apply thus, the booming

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9

Laws to regulate groundwater use such as the requirement that users install flow meters at their wells and report the volume of water pumped have not been enforced. There are also indications that non-authorized excavations and use of well water still abound.

business of consultants doing everything from project initiation to its completion, 'clé en main'. Furthermore, there are no clear standards by which to compare prices, a lack of transparency (e.g., service fees were often embedded with materials costs) and possibly not enough warranties to ensure the system's longevity.

Research and outreach

The design and operation of drip irrigation systems in Morocco improved over the years due to, among other things, experience, generous government subsidies, which since 2002 have been tied to a rigorous review process; and increased competition among drip irrigation consultant and supply companies. However, there is plenty room for improvement! For example, Bouazzama and Bahri (2007) reported that 43% of the citrus orchards surveyed did not have soil or leaf test results on which to base their fertigation programs. Also, there did not seem to be much guidance in scheduling irrigations other that what the original design called for. Managing drip irrigation so that it produces the expected results (e.g., water conservation and an increase in crop yield and quality) requires experience and a departure from old habits (Burt and Styles, 1999)[10]. Experience will come from increased involvement of farm owners and managers in the design, operation, and maintenance of drip irrigation. It will be reinforced by research and outreach, which needs to be stepped up to match the determination and enthusiasm with which the government of Morocco is pursuing the goals set by PNEEI.

One area where research is lacking is subsurface drip irrigation or SDI. With SDI, drip tapes should not interfere with field operations such as row cultivation or crop harvest. Another advantage is reduced water evaporation from the soil surface, the extent of which will vary depending on drip tape placement depth, irrigation depth, soil type, etc. Adequate filtration and maintenance (e.g., flushing the driplines regularly and injecting acid to dissolve mineral deposits) will keep the system running for a long time. Leaks in the drip tapes can develop due to damage from tillage implements (e.g., if the drip tape is not deep enough) or from rodents and may be a challenge to fix. SDI would be ideal in Morocco for row crops such as corn and sugar beets and even solid-seeded crops such as alfalfa and wheat but would require more management skills than non-SDI systems. SDI can be designed to accommodate several crops in rotation but research is needed to determine the optimum drip tape placement depth and lateral spacing, etc.

Conclusions and recommendations

The 2008/2009 season brought much needed relief (in the form of snow and rain) to an otherwise bleak picture of meeting the demand for water in Morocco. In 1994-2006, only 44% (on average) of the normal allocation for ag water was met nationally, due to frequent droughts, increased demand for municipal and industrial water, siltation of water reservoirs, etc. Nonetheless, agriculture still uses a large share (80 to 90%) of the available water and, by some accounts, "wastes" a good deal of it (Berrada, 2005). This is mainly because of inefficient flood-irrigation systems such as the 'Robta' that is predominant in the irrigated perimeters.

10

Unlike flood irrigation, drip irrigation requires frequent water applications (usually in small amounts); otherwise it would be difficult to catch up, i.e., meet crop water demand.

To conserve water and optimize its use efficiency (produce more with less!), the government put forth an ambitious plan by which 700,000 ha of cropland would be equipped with drip irrigation by 2022. Already 163,000 ha were fitted with drip irrigation at the end of 2008. The primary tool used to entice landowners and managers to adopt this technology is a subsidy of 60% of the drip irrigation installation cost estimated at $7,500/ha if a storage reservoir is built. The average cost (based on subsidy requests) at PIT averaged $5,725/ha from 2002 through 2008 and varied from year to year and with land size, degree of sophistication, crops grown, etc.

Over 80% of the land equipped with drip irrigation at PIT consisted of fruit orchards, which made sense economically and technically. Only recently (e.g., after the subsidy was increased to 60% in 2007) has the number of subsidy requests for non-tree crops (mostly sugar beets) picked up. In order to reach the goal set by PNEEI to equip 88,740 ha or 81% of the total irrigated land at PIT with drip irrigation, the government will build the infrastructure to bring pressurized water to 49,000 ha of cropland. This is because small farmers (80% of the farms at PIT are < 5 ha) who grow mostly wheat, barley, alfalfa, and sugar beet cannot afford drip irrigation (on their own), are not familiar with it, or are not convinced that it would work for them. These so-called 'projets collectifs' present, in my view, the biggest challenge to the government's ability to fulfill the goals set by PNEEI. The program is already popular among private landowners, particularly outside the government-sponsored irrigation projects but it could be an uphill battle to convince subsistence farmers to switch to drip irrigation. Nonetheless, the government is working diligently to bring about change in anticipation of future water shortages[11].

Drip irrigation is not a panacea but may be the best hope to conserve water and enhance agricultural productivity and sustainability in Morocco. It may not work for every situation, thus it is prudent to continue efforts to improve existing irrigation methods. Similarly, it is prudent to start small (e.g., pilot projects) before investing too much in collective projects. More importantly, property owners' and growers' associations should be allowed and encouraged to assume more responsibility in the design, installation, and management of drip irrigation projects. This would bring down the cost and ensure the project's sustainability. Finally, research and education should be stepped up to:

- Develop drip irrigation systems and best management practices adapted to the climatic, soil, social, and economic conditions of the various agricultural production zones in Morocco.
- Demonstrate the benefits of drip irrigation for various crops and conditions.
- Teach farmers how to design[12], install, and manage drip irrigation.

11

Recently the government of Morocco launched what is called 'Plan Maroc Vert' or 'Green Morocco' to (1) develop a modern and highly performing agriculture through private investments and, (2) enhance small-scale agriculture to combat poverty.

12

This may be a challenge for older or illiterate farmers but they should at least be taught the basics of drip irrigation design and how the various components work. Moroccans farmers are smart, regardless of their degree of schooling!

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