Chapter 9: Adoption and impact of supplemental irrigation in wheat-based systems in Syria

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9.1 Introduction

Agriculture in Syria depends on a wide base of varied natural resources extending over five agro-ecological zones differing in total precipitation, soil structure, and water resources such as rivers, springs, dams, and groundwater which supplies water for about 851,000 ha (61% of the total irrigated areas). However, precipitation is considered as the main source of the water needed to establish the widespread rainfed system of agriculture, which occupies 70% of the cultivated area in Syria (Ministry of Agriculture, 2006).

In Syria, wheat is the most important winter crop and is grown on about 1.8 million hectares (about 32% of the total cultivated area). This area includes two farming systems – irrigated and rainfed (45% and 55% of the wheat area, respectively). Statistics show that the productivity of irrigated wheat has increased over the last five years due to new irrigation technologies.

However, new irrigation technologies have low levels of adoption. They cover only 17% of the total irrigated area (about 236,000 ha). The degree of adoption of sprinkler systems was estimated at 69%, greater than that of drip irrigation at 31% (Ministry of Agriculture, 2006).

As wheat is the major user of cultivated land and also of water resources among all winter crops, it was considered as the basic crop in this project undertaken by ICARDA as a joint program in Syria.

9.1.1 Objectives

- Studying the adoption indicators of supplemental irrigation and new irrigation technology in wheat-based systems.
- Identification of the factors restricting adoption.
- Estimating the impact indicators of adoption.

9.1.2 Characterization of the study area

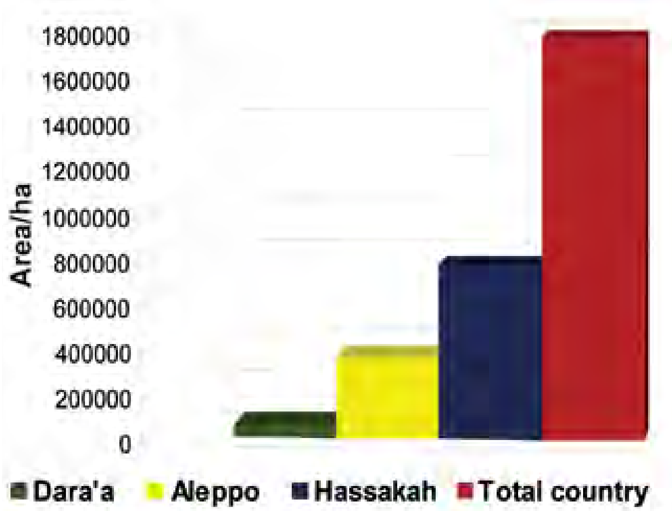
The three most important provinces applying supplemental irrigation in wheat-based systems in Syria have been involved in the project. These are Aleppo in the northwest of the country, Dara'a in the south, and Hassakah in the north east. They account for about 61% of the total production of wheat in Syria (Table 9.1).

Table 9.1: Total production of wheat in the study area during the year 2006.

Province	Production (ton)	% of total country production
Dara'a	99,091	2
Aleppo	1,002,093	20
Hassakah	1,897,934	39
Total of the study area	2,999,118	61
Total of the country	4,931,525	100

In addition, these important provinces account for about 66% of the total area planted to wheat (Figure 9.1)

Another important point is that over the last decade these provinces hosted irrigation field trials conducted by ICARDA and the National Agricultural Research Program (NARP) represented by the Administration of Irrigation Research. These trials focused on supplemental irrigation, deficit irrigation, water timing and scheduling in wheat with various levels of fertilizer and several varieties. The villages involved in these trials were already included in the sampled community, and fifteen villages were selected to be surveyed. Five villages were selected from each province in agro-ecological zones 1 and 2.



Source: Ministry of Agriculture and Agrarian Reform (2006).

Figure 9.1: Area planted to wheat in the study area during the year 2006.

Farmers in the study area have various sources of water. In Aleppo and Hassakah provinces, they depend mainly on groundwater where they own wells. The discharge of farm water is 10–130 m^3/h and 30–295 m^3/h in the two provinces, respectively. However, farmers in Dara'a province depend on two sources of water, wells and canals which have been established by the government to draw water from dams to farmers' fields. Discharge from wells in Dara'a is 22–80 m^3/h, while the discharge from canals is 18–84 m^3/h.

Both farming systems – rainfed and irrigated – exist independently in the study area. However, some farmers grow wheat as both irrigated and rainfed simultaneously, depending on water availability. The average precipitation varies in the study area. It was 376 mm, 350 mm and 291 mm in Aleppo, Dara'a and Hassakah, respectively, while it was 398 mm in zone 1 and 293 mm in zone 2.

As a Mediterranean country, Syria is characterized by a low annual level of precipitation, unfavorably distributed over the growing season, with great year-to-year fluctuations, which make the prediction of annual rainfall very difficult (Oweis, 1997). So, if farmers depend only on precipitation, they are taking a risk with their production. Therefore, they mostly depend on supplemental irrigation to support crops, especially wheat, when precipitation fails to supply the needed water.

9.2 Methodology

During the initial stages of the project, a check list including all relevant thoughts and important points was developed with the participation of ICARDA scientists and a team from the General Commission for Scientific Agricultural Research (GCSAR) to cover all options that will lead to achieving the project goals in Syria. The check list included the technical and socioeconomic information needed to understand the farmers' irrigation practices, cropping patterns, water sources and allocation, adoption of new technologies and recommendations, and farmers' concepts about water management, as well as farm management and production costs.

A rapid rural appraisal (RRA) was included in this check list and carried out with the participation of various levels of the community (farmers, extension agents, researchers) in irrigated and rainfed areas. At the subsequent stage, a primary questionnaire was designed, and a pre-testing survey was carried out. The results of the pre-testing stage helped in gaining more understanding of the community situation, and in bringing out other new points, which had to be added to the questionnaire later.

9.2.1 Sample size and allocation

The three provinces included in the survey were described. Results showed that each province could be distinguished by its specific characteristics based on farm size, cropping patterns and water resources. This led the study team to adopt a stratified sampling approach, since it helped to consider each province as a uniform stratum. The stratified sample is the one obtained by separating the population elements into non-overlapping groups, called strata, and then selecting a simple random sample from each stratum.

Following the stratified sampling approach, sample size was calculated according to the variance in farm size (calculated from the pre-testing data). On this basis, 490 farmers were interviewed throughout the study area in the three provinces.

The calculated sample size was allocated to various levels:

1. First level is the province.
2. Second level is the agro-ecological zone.
3. Third level is the village, and
4. Fourth level is the source of water, as shown in Figure 9.2.

The sample allocation resulted in 265 farmers located in eight villages in zone 1, and 225 farmers located in seven villages in zone 2, as shown in Table 9.2.

9.2.2 Data collection

The questionnaire used in the study aimed to collect the following data:

- Participation of farmer in previous trials and activities on irrigation.
- Soil type and characterization.
- Agricultural rotation and cropping pattern.
- Land tenure.
- Farm water sources.
- Production costs.
- Farm water use.
- Irrigation system infrastructure on the farm, and its cost.
- Application of supplemental irrigation and adoption of new irrigation technologies.

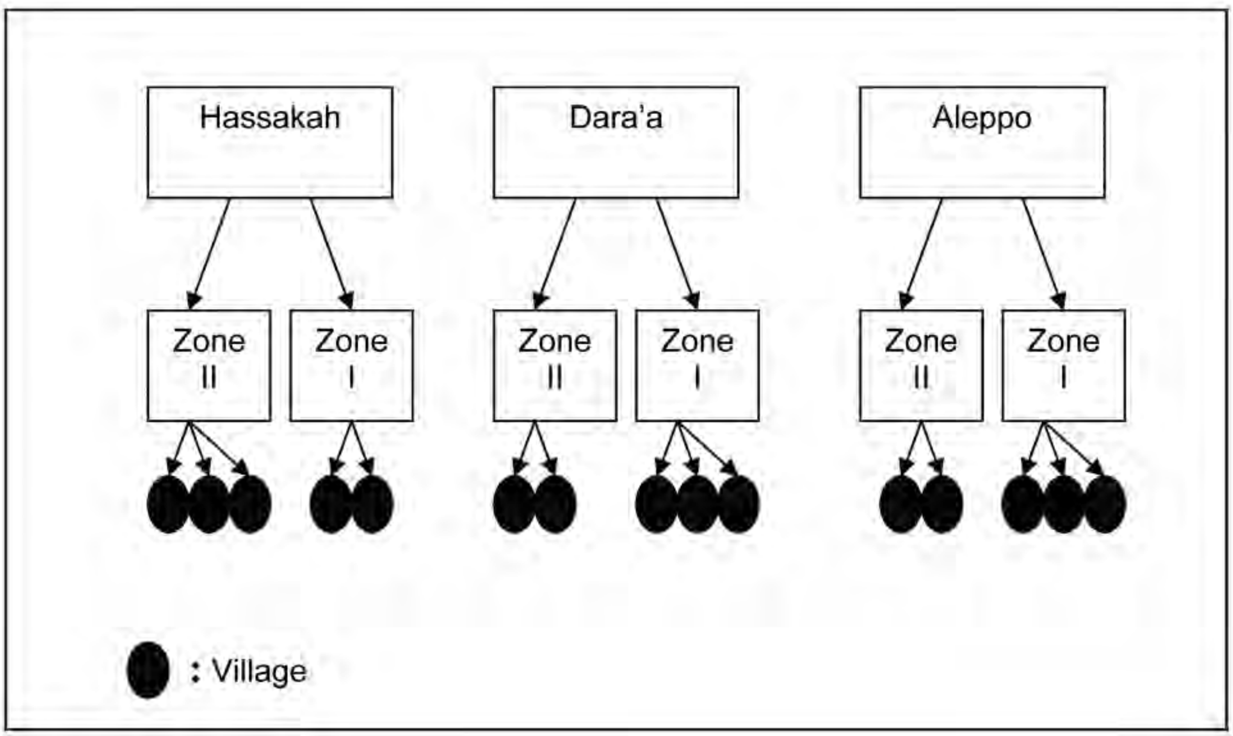


Figure 9.2: Sample allocation.

Table 9.2: Sample allocations by province and agro-ecological zone (AEZ).

Province	**Aleppo**		**Dara'a**		**Hassaka**	
AEZ	I	II	I	II	I	II
Sample size	175	56	55	104	35	65
Province total	231		159		100	

Note: AEZ: agro-ecological zone.

- Obstacles to the adoption of technologies.
- Income sources.
- Household structure and farmer's socioeconomic characteristics.
- Information sources.
- Farmer's self-concepts.

The group of 490 farmers was interviewed in the three selected provinces. The field survey also included measurements of water discharge from both sources – wells and canals.

Data analysis was carried out using the SPSS program (Statistical Package for the Social Sciences) at two main levels, province and agro-ecological zone (1 and 2), and at a third level, the water source, when dealing with production and irrigation indicators.

9.3 Results and discussion

9.3.1 Land tenure and cropping patterns

The average total farm size in the sample was 14.7 ha, not all of which was owned by the farmer; the average owned area was 12.7 ha. The area not owned was mainly rented or partly-shared. The survey showed that total and owned areas were larger in zone 2 (Table 9.3).

From Table 9.3, we can infer that the renting level in Aleppo and Dara'a is higher than in Hassakah, and also in zone 1 when compared with zone 2. This is because of the small size of holdings in these areas, prompting farmers to find an additional source of income. It is also clear that the level of sharing is low in the study area, although it is somewhat higher in Dara'a, Aleppo and in zone 1. This reflects the farmer's concept of economic investment and usage of production resources, and perhaps also the social relationship between community members.

In the survey area, winter crops occupy 63% of the total cultivated area in our sample, while summer crops account for about 24%, fruit trees for 2% and 11% of the total land is under rainfed systems (Figure 9.3). Some farmers overlap rainfed systems with irrigated

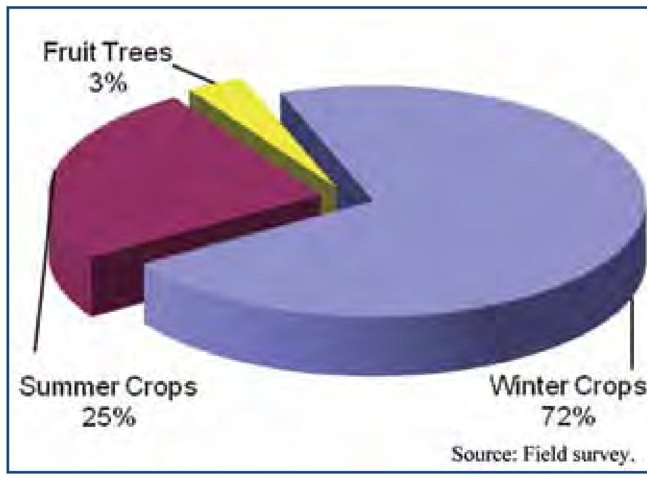


Figure 9.3: Cropping patterns in the study area.

Table 9.3: Land tenure information calculated by the survey.

Land tenure		Aleppo	Dara'a	Hassakah	Area (ha) Zone 1	Area (ha) Zone 2
Total	Area	9.8	9.7	34	11	19
	Total farmers	231	159	100	265	225
Owned	Area	8.6	8.5	34	9	19
	Number of farmers	227	144	90	254	207
Rented	Area	5	7	30	7	11
	Number of farmers	65	44	14	81	42
Shared	Area	4	3	60	3	13
	Number of farmers	9	8	1	12	6

Source: Field survey.

systems. Wheat is considered the dominant crop and occupied 12% of the cultivated area, which is 37% of the area under winter crops. On the other hand, cotton is considered the most important summer crop, and it occupies 21% of the area under summer crops (7% of the total cultivated area). This is in spite of the restrictive policies limiting the area allocated to cotton due to water resources and usage.

Although the three provinces have wheat as a major crop, they differ in other crops. Wheat forms 11%, 9%, 48% of the total cropped area in Aleppo, Dara'a and Hassakah, respectively. Other than wheat, Aleppo is characterized by barley, cotton, sugar beet, potato, olive, fruit, vegetables, and other crops such as cumin, maize, some legumes and others. While Dara'a is characterized by chickpea (more important than wheat accounting for 11% of the cultivated area), melon, potato, legumes, fruit, vegetables, grapes, olive, tobacco and stone fruit. Hassakah is characterized by cotton, barley and some other crops such as some legumes and maize.

The relative importance of winter crops in the cropping pattern in zone 1 decreases in comparison with zone 2 (60% versus 65%). However, summer crops are more important in zone 1. This is due to the large average farm size in zone 2, and the importance of using water for growing winter crops. The shortage of water in zone 2 restricts raising summer crops, which consume more water than winter crops. There was no difference in their relative importance of fruit trees.

Wheat is included in almost all crop rotations. The main rotations in Aleppo are wheat–legumes, wheat–cotton–potato and wheat–potato–sugar beet–cotton, representing 20%, 18% and 11%, respectively. In Dara'a, the main rotations are wheat–vegetables, wheat–legumes and wheat–fallow, accounting for 50%, 19% and 12%, respectively. However, in Hassakah there are five types of agricultural rotations which are wheat–cotton, wheat–cotton–legumes, wheat–legumes, cereals–cereals, and wheat–cotton–maize–potato accounting for 92%, 6%, 1%, 1%, and 1%, respectively.

9.3.2 Farm water resources and irrigation infrastructure

The main sources of water are wells for groundwater and canals for surface water. In Aleppo and Hassakah, wells are considered the main water source in the area surveyed. However, in Dara'a, wells are the water source for 45% of farmers, while canals provide water for 67% of farmers, and 15% of farmers have both sources of water on their farms. The average number of wells on the farm is one in the three provinces, but varies from one to three in the sample, with no significant differences. But, the percentage of owners of wells differs significantly within zones and insignificantly within provinces, as shown in Table 9.4.

Fifty percent of farmers in the sample, who depend on groundwater for irrigation, said that water levels had fallen over the past few years. The majority was in Aleppo (60%), 49% in Hassakah and only 11% in Dara'a. The critical period when water levels decline occurred between June and August, while it was concentrated in May in zone 2, and July and August in zone 1. The average fall in groundwater levels per year is illustrated in Table 9.5.

Table 9.4: Percentage of well owners according to number of wells owned.

Number of wells	Province			Zone		Total
	Aleppo	Dara'a	Hassakah	I	II	
1	77	89	82	82	76	80
2	18	9	13	16	14	15
3	5	2	5	2	10	5

Source: Field survey.

Table 9.5: Average fall in groundwater levels.

Fall in water level	Province			Zone		Total
	Aleppo	Dara'a	Hassakah	I	II	
Average (m/year)	0.49	0.19	0.19	0.36	0.44	0.39

Source: Field survey.

The average fall in groundwater levels per year was 0.39 m in the sample. It approached 0.19 m in Dara'a and Hassakah, while it was 0.49 m in Aleppo. These differences relate to the physical conditions of the groundwater basin, farmers' irrigation behavior and the water renewal ability. It is interesting to note that water decline in zone 2 is greater than the decline in zone 1 (0.44 m vs 0.36), indicating greater water withdrawal in zone 2 compared to zone 1, where crop water requirements are lower as illustrated in Figure 9.4.

Farmers have been drawing water for periods ranging from 2 to 65 years, while the average age of the wells is 21 years. In zone 1, the period of use ranges from 2 to 50 years, and the average age of wells is 21 years, while in zone 2 the period of use ranges from 1 and 65 years, and the average age of wells is 20 years. The cumulative percentage of the age of wells shows that farmers in zone 2 invested in irrigated agriculture before those in zone 1. This may be because of rainfall deficiencies in zone 2, where rainfed farming systems have a high degree of risk, relatively higher than in zone 1. On the other hand, according to the age of wells, investment in irrigated agriculture using groundwater started earlier in Aleppo (23 years) than in Dara'a (19 years), and even later in Hassakah (17 years).

Two types of wells are found in the study area – artesian and chuckhole in Aleppo, but only artesian in Dara'a and Hassakah. Artesian wells are more recent (up to 20 years), while chuckhole wells are older (up to 27 years).

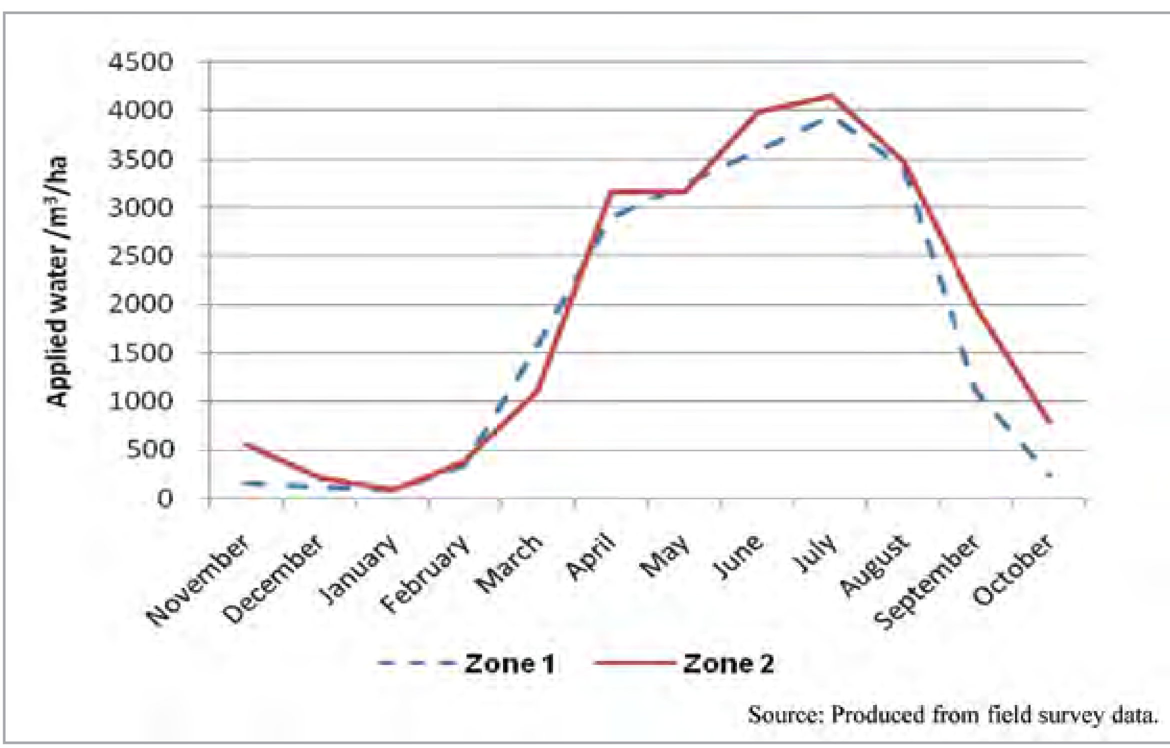


Figure 9.4: Average amount of water applied at the farm level in zones 1 and 2 by month.

This relationship between type of well and its age is highly significant. All the chuckholes are located in zone 2 in Aleppo. The wells involved in the survey are similar in some specifications but differ in others, as shown in Table 9.6.

9.3.3 Methods of irrigation and farm water use

The main irrigation methods that farmers use are surface, sprinkler and drip irrigation. These methods varied according to the type of crop. Therefore, farmers may adopt more than one method, as shown in Table 9.7, considering the most important crops.

Table 9.6: Specification of wells.

Specifications	Province				Zone		Total	
	Aleppo		Dara'a	Hassakah	I	II		
	Artesian	Chuckhole	Artesian	Artesian	Artesian	Artesian	Artesian	Chuckhole
Depth (m)	246	58	79	188	240	154	206	58
Water level (m)	113	40	49	59	110	51	87	40
Pump diameter	3.7	3	3.8	6	4.3	5	4.6	3

Table 9.6 shows that there are considerable differences in the depth of wells, and consequently in groundwater levels between the provinces, and also between the two types of well in Aleppo, increasing the cost of pumping as the groundwater level goes down. Also, the greater the diameter of the pump, as in the case of Hassakah, leads to more water being pumped per unit of time. All these differences are highly significant ($p<1\%$) between provinces, and between the two types of well in Aleppo.

Water quality in Aleppo and Dara'a is fresh (94% and 98% responded respectively), where 3% of farmers in Aleppo said that the water on their farms is slightly saline, 0.5% that they have saline water and 0.5% that they have sulfur in the water. While in Dara'a, 1% of farmers have saline groundwater and 1% sewage water. In Hassakah, the situation was different, since only 52% of farmers have fresh groundwater and the most important feature of water is sulfur (37% of farmers). In addition, 11% of farmers considered their water to be moderately saline, while 5% considered it saline, and 1% said that their water is calcareous. In spite of salinity, 32% of farmers intend to continue irrigation regardless of the negative effects, 13% of them in Aleppo and the others in Hassakah. However, the rest have strategies to deal with salinity by following crop rotations such as wheat–legumes, including faba beans.

Table 9.7 shows that the dominant method is surface irrigation and all crops are irrigated by this method. Farmers may use more than one method for the same crop, such as wheat in separate plots. On the other hand, some farmers combined surface and sprinkler irrigation or sprinkler and drip irrigation.

They used the first type (surface or sprinkler) on cotton and corn, and the second (sprinkler or drip) on cucumber. That is, from their point of view, to save water by using sprinkler irrigation at the early stages of cotton growth and to prevent local soil erosion, which protect seeds before germination. However, they prefer, after two to three sprinkler irrigations, to continue using surface irrigation, which, they believe, provides more water for better growth and production, and avoids the damage resulting from sprinkler irrigation during the later stages of cotton growth (such as fungal diseases).

Water applied to crops varied according to the crop, planting season and the farmers' perspective. The amounts of water, as illustrated in Figure 9.5, represent farm water supply without rainfall. The coefficient of variation in water supply among farmers is greater for summer crops than for winter

Table 9.7: Distribution of farmers according to the irrigation methods used.

Crop	Surface (%)	Sprinkler (%)	Drip (%)	Combination surface and sprinkler (%)	Combination sprinkler and drip (%)	Total number of farmers
Wheat	63	37	0	0	0	430
Cotton	63	0	15	22	0	241
Potato	6	88	6	0	0	83
Tomato	13	0	88	0	0	64
Eggplant	25	0	75	0	0	53
Faba bean	64	32	4	0	0	50
Cucumber	22	2	73	0	2	45
Fruit trees	29	0	71	0	0	45
Garlic	61	32	8	0	0	38
Sugar beet	52	48	0	0	0	33
Pepper	41	0	59	0	0	31
Maize	43	29	0	28	0	14
Melon	23	0	77	0	0	13
Lentil	80	20	0	0	0	10
Barley	75	12.5	12.5	0	0	8
Tobacco	100	0	0	0	0	7
Chickpea	80	20	0	0	0	5

Source: Field survey.

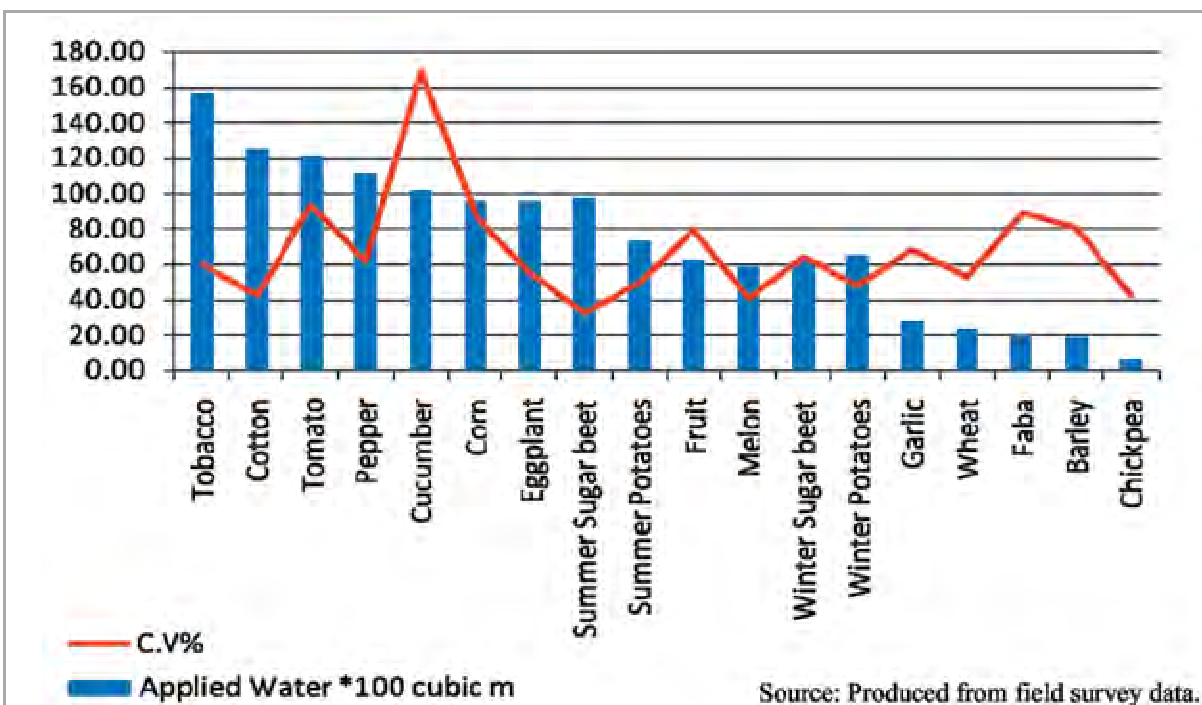


Figure 9.5: Average amount of water applied to the dominant crops at the farm level.

crops. This indicates the relative stability in applied water in the winter season, and the behavioral approach that farmers follow to estimate irrigation requirements.

The amounts of irrigation water also varied according to the agro-ecological zones. Figure 9.6 shows the differences between the zones 1 and 2 among crops. For winter crops and fruit trees, it is obvious that farmers supply more water for their crops in zone 2. The surplus sometimes reaches more than 100% as in the cases of garlic, faba bean and lentil (Table 9.8).

There is no rule that controls irrigation water quantities between the two zones for summer crops. It is based on the farmers' experience or tradition and water availability. The survey data indicated high water discharge and high duration of irrigation in zone 2 as compared to zone 1.

9.3.4 Supplemental irrigation

Shideed et al. (2003) have defined supplemental irrigation as adding a quantity of water to rainfed crops during the period in which rainfall is not adequate to keep soil moisture at a level that can enable the plant to continue growing. It aims to improve productivity and stability. This means that if the target crop is rainfed it will give a specific level of production without any irrigation, but if supplemental irrigation is not applied when rainfall stops production will be negatively affected.

Table 9.9 shows the distribution of farmers who have heard about and adopted supplemental irrigation. Generally, it is not necessary for the farmer to know what supplemental irrigation means before they adopt it. In fact, most farmers apply supplemental irrigation at a time when they do not know exactly what it means. About 83% our sample farmers, who own water sources, have heard about supplemental irrigation, and 72% of them have adopted it. However only 21% of farmers are aware of supplemental irrigation in its proper form, and received information through communication channels such as extension, public media, neighbors, and ICARDA scientists.

Table 9.9 clearly shows that the rate of adoption in Dara'a is the highest, 87%, while

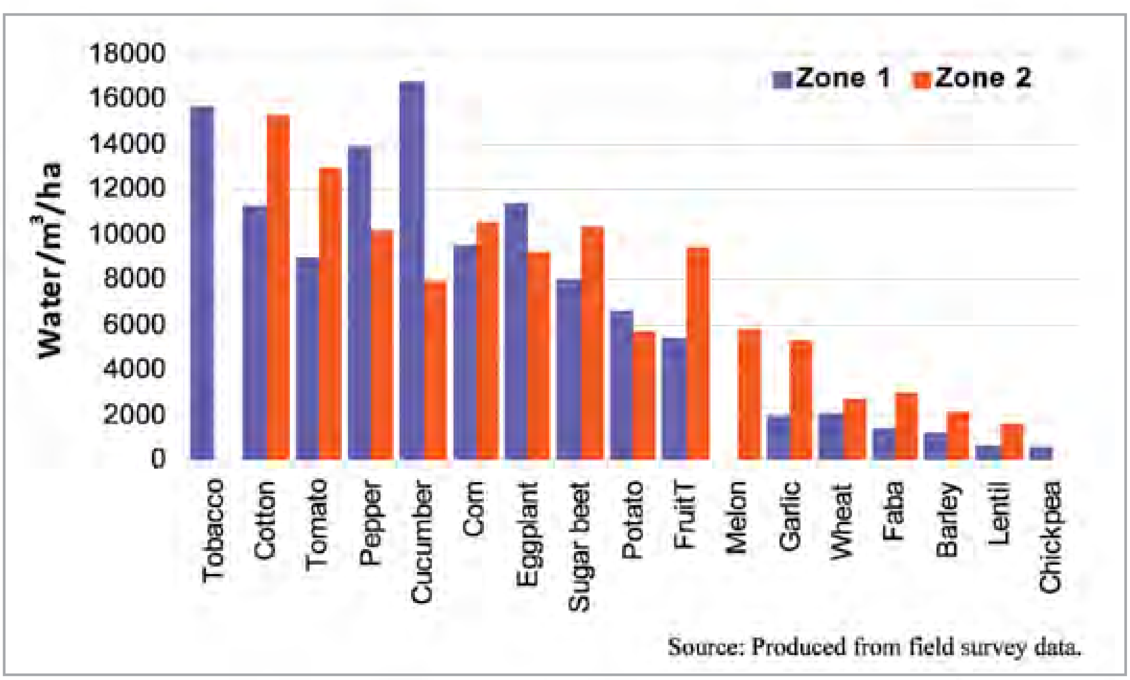


Figure 9.6: Irrigation water supply in zone 1 and zone 2 for several crops.

Table 9.8: Comparison of water applied (m³) in the two agro-ecological zones.

Crop	Zone 1		Zone 2		Change in water supply from 1 to 2
	Mean	SD	Mean	SD	
Tobacco	15,673	9481	–	–	–
Cotton	11,304	5079	15,311	4714	35%
Tomato	8948	3548	12,998	12,596	45%
Pepper	13,881	4414	10219	7300	-26%
Cucumber	16,768	32,033	7970	8001	-52%
Maize	9529	8645	10,500	1 obs.	10%
Eggplant	11,339	3759	9262	5506	-18%
Sugar beet	8063	2642	10,333	2893	28%
Potato	6636	3111	5677	2878	-14%
Fruit trees	5434	5198	6424	5562	18%
Melon	–	–	5798	2332	–
Garlic	1988	818	5289	2159	166%
Wheat	2061	1118	2688	1287	30%
Faba	1396	1335	3003	1986	115%
Barley	1190	608	2120	1698	78%
Lentil	621	305	1611	2252	159%
Chickpea	529	225	–	–	–

Source: Field survey.

Table 9.9: The number and percentage distribution of adopters of supplemental irrigation.

	Province						Zone				Total	
	Aleppo		Dara'a		Hassakah		I		II			
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Heard about	204	88	158	99	46	46	236	89	172	76	408	83
Adopted	172	75	139	87	39	39	187	71	163	72	350	72

Source: Field survey.

in Aleppo it is 75%, and in Hassakah it is the lowest (only 39% of those who have water available on their farms).

These differences in the degree of adoption of supplemental irrigation between the three provinces are significant at the 1% level. On the other hand, the rate of adoption of supplemental irrigation in zone 1 (71%) approaches the rate in zone 2 (72%).

Those farmers, who have not adopted supplemental irrigation, form 27% of the total sample. They said that they are not satisfied with supplemental irrigation, because they believe that if they supply the crop when a lot of water it will give more yield regardless of the quantity of available rainfall.

9.3.5 Adoption of new irrigation technologies

Farmers are using surface irrigation, sprinkler, drip or a combination of irrigation systems. Surface irrigation is dominant in Hassakah (97%), sprinkler in Aleppo (79%) and drip irrigation in Dara'a (60%). However, sprinkler irrigation is dominant in zone 1 (65%), while surface irrigation is widespread in zone 2 (93%) as reported in Table 9.10.

Table 9.10: Rate of adoption of new irrigation technologies.

	Province (%)*			Zone (%)*		Total*	
	Aleppo	Dara'a	Hassakah	I	II	No. observations	%
Surface	48	92	97	55	93	320	74
Sprinkler	79	8	6	65	10	170	39
Drip	25	60	15	22	49	151	34

Source: Field survey. *Some farmers are using more than one system.

Since summer vegetables and fruit trees are relatively widespread in Dara'a, and since farmers have adopted drip irrigation for use with these crops, Dara'a has the highest rate of adoption of drip irrigation. Similarly, the spread of sprinkler irrigation in Aleppo is attributed to the diversity of winter crops, which are mainly irrigated by sprinkler (wheat, faba bean, sugar beet, garlic), in addition to summer crops such as potato. In Hassakah, wheat is more important in the cropping pattern compared with the other two provinces, but there is no diversity of crops as in Aleppo or Dara'a, and farmers prefer surface irrigation. The differences in the importance of the crops and their methods of irrigation were significant at 1% level.

The degree of adoption has been defined by Shideed et al. (2005) as a measure using the proportion of land under the new technology, which in this study means the proportion of land irrigated by new irrigation technologies – sprinkler and drip. The degree of adoption of sprinkler irrigation is 78% in Aleppo, whereas in Dara'a it is 38% and in Hassakah, 21%. However, the degree of adoption of drip irrigation is 24% in Aleppo, 45% in Dara'a and 43% in Hassakah.

It is noticeable that the highest degree of adoption for wheat and cotton crops is surface irrigation, while the degree of adoption of sprinkler is high for crops such as potato and sugar beet (Table 9.11).

The degree of adoption of sprinkler irrigation in cotton farming reflects the use of the sprinkler system during the initial stage of crop growth before converting to surface or drip irrigation when the crop reaches the stage where it becomes leafier.

9.3.6 Constraints to the adoption of new irrigation technologies

The high cost of new irrigation systems was the most important constraint to the adoption at the sample-, province-, and zone-levels, where 69% of farmers attributed non-adoption to their financial position and the high cost of such systems. However, water scarcity was an obvious constraint to adoption in Dara'a province, where some famers do not control their water, especially those who received water from governmental sources. On the other hand, water quality was a very important problem in the adoption of new irrigation technology, since 21% of farmers suffer from sulfur-laden water. Also, some farmers (2% of the sample) have some difficulties with their fields, such as field length, slope or size. Sometimes, farmers are not convinced by the new irrigation technologies and prefer surface irrigation. 6% of the sample mentioned this (Table 9.12).

9.3.7 The impact of supplemental irrigation

As this study focused on wheat-based systems, we will concentrate on wheat as the main target crop when looking at indicators of the impact of supplemental irrigation and new technologies.

Adopters of supplemental irrigation who used groundwater gained 20,823 SL/ha (SL = Syrian pound) net return, compared to non-adopters, who used more water but whose gain was only 15,386 SL/ha (Table 9.13).

Water productivity (WP), the other indicator of the benefit of supplemental irrigation,

Table 9.11: Degree of adoption of new irrigation technologies for several crops (%).

Crop	Method of irrigation	Aleppo		Dara'a		Hassakah		Zone 1	Zone 2	Total
		Z 1	Z 2	Z 1	Z 2	Z 1	Z 2			
Wheat	Surface	3	67	60	81	100	92	27	81	52
	Sprinkler	77	8	4	4	0	6	52	5	30.5
	Rainfed	20	25	36	15	0	2	21	14	17.5
Cotton	Surface	25	50	0	0	90	86	39	81	52
	Sprinkler	60	0	0	0	0	4	47	4	34
	Drip	15	50	0	0	10	10	14	15	14
Potato	Surface	14	0	50	6	0	0	15	6	14
	Sprinkler	86	100	50	31	0	0	85	39	80
	Drip	0	0	0	63	0	0	0	55	6
Sugar beet	Surface	7	75	0	0	0	0	7	75	15
	Sprinkler	93	0	0	0	0	0	93	0	82
	Drip	0	25	0	0	0	0	0	25	3

Source: Field survey.

Table 9.12: Constraints to the adoption of new irrigation technologies.

Constraint	Province (%)*			Zone (%)*		Total*	
	Aleppo	**Dara'a**	**Hassakah**	**I**	**II**	**No.**	**%**
Water scarcity	13	32	1	18	11	22	14
High cost	91	65	65	71	68	110	69
Water quality	0	0	41	3	31	33	21
Farm size	0	2	3	0	3	3	2
Not convenient	0	5	9	7	6	10	6
High depreciation	0	0	5	7	0	4	3
Policies	0	5	1	5	1	4	3

Source: Field survey. *Some farmers have more than one constraint.

Table 9.13: Impact of supplemental irrigation on net returns and water productivity in wheat farming based on groundwater.

	Net return SL/ha	**WP kg/m³**
Adopters	20,823	0.94
Non-adopters	15,386	0.80

Source: Field survey. SL: Syrian pound; WP: water productivity.

is defined by Shideed et al. (2005) as the ratio of crop production (kg) to the unit of water used (m^3). Water productivity has been calculated as a ratio of production to total water applied, including rainfall. Supplemental irrigation has resulted in an increase in water productivity for adopters compared to non-adopters (0.94 kg/m^3 vs 0.8 kg/m^3), a highly significant difference ($p<1\%$) as shown in Table 9.13.

9.3.8 The impact of new irrigation technologies

The impact of the new irrigation technologies can be assessed from farm water savings when compared with traditional methods of irrigation, and with respect to the type of crop. In the case of wheat, farm water savings can be achieved by adopting new technology such as sprinklers, as shown in Table 9.14. The average quantity of water used per unit area is 1988 m^3/ha under sprinkler irrigation whereas it is 2582 m^3/ha with traditional surface irrigation

Table 9.14 clearly shows that adoption of sprinkler irrigation technology results in using less water overall. However, it also shows that in Dara'a province, the quantity of water per unit area is slightly higher when using this technology. That is because water flows from canals controlled by the government, and farmers have to use the entire quantity they receive. In Hassakah, the small number of sprinkler irrigation adopters versus the large number of surface irrigation users, discharging a large amount of water, reduces the difference in water quantity between surface and sprinkler irrigation. We faced a similar situation in zone 2, where the difference was too small to determine the impact of the technology. However, the weather and precipitation conditions in zone 2 pushed farmers to supply winter crops with more water regardless of other factors.

The other indicator of the impact of new irrigation technologies in wheat farming is the net return (Table 9.15). Farmers who adopted sprinkler irrigation gained greater net returns than those who continued using the traditional methods of irrigation. This difference is very marked in Dara'a and Hassakah. This result is caused by the domination of surface irrigation in wheat farming when compared with sprinkler irrigation.

Water productivity (WP) is also an indicator to demonstrate the impact of irrigation technology. Although it helps the farmer to save water, the contribution of average rainfall to crop production may confuse its impact, especially when it is high in the areas under technology adoption. WP calculated considering the total water applied, including rainfall, is shown in Table 9.16.

Table 9.16 shows that the adoption of new irrigation technologies can result in an improvement in water productivity. Sometimes, the high average rainfall in areas under new irrigation technology can be misleading and mask its real impact, especially if rainfall is not as high in areas under traditional irrigation methods.

Table 9.14: Impact of adopting new technology on groundwater use in wheat farming.

Water by irrigation method (m^3/ha)	Province			Zone		Total
	Aleppo	Dara'a	Hassakah	I	II	
Quantity of water by surface irrigation	3146	1717	3458	2322	2690	2582
Quantity of water by sprinkler irrigation	1957	1736	3318	1924	2652	1988

Source: Field survey.

Table 9.15: Impact of adopting new technology on net returns in irrigated wheat farming based on groundwater.

Technology	Province			Zone		Total
	Aleppo	Dara'a	Hassakah	I	II	
Surface irrigation (SL/ha)	18,223	19,842	8918	11,212	14,308	13,661
Sprinkler irrigation (SL/ha)	23,488	33,600	20,054	23,190	28,899	23,702

Source: Field survey. SL: Syrian pound.

Table 9.16: Impact of adopting new technology on farm water productivity.

Technology	Zone I	Zone II	Total
Surface irrigation (WP kg/m^3)	0.77	0.92	0.86
Sprinkler irrigation (WP kg/m^3)	0.91	1.11	0.93

Source: Field survey. WP: water productivity.

9.4 Conclusions

Wheat is the most important crop cultivated in Syria, where supplemental irrigation has gained high importance as an approach to irrigation. In the target area of this study, groundwater is the main source of irrigation, which varies between traditional and modern. The study found that supplemental irrigation improves water productivity, and the adopters of this approach to irrigation achieve higher net returns when compared with non-adopters.

The adoption of new irrigation technology in wheat farming results in farm water savings and higher net returns, when compared to farmers using traditional irrigation. In spite of this, the adoption rate of new irrigation technologies is still low compared to surface irrigation. The reluctance of farmers to adopt new irrigation technologies is due to the high cost, water quality and water scarcity.

9.5 References

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