

## **Drought Mitigation: Assessing Technological Options and Challenges Posed by Policy Solutions: A Case-Study of Salamieh District, Syria**

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**Abstract:** Syria is a largely arid and semi-arid country prone to water shortage, due in part to low levels of precipitation and inefficient management of water supplies. Periodic droughts exacerbate the problem of water shortage and place greater risks on livelihoods. One of the areas affected is Salamieh District, located in central Syria, which relies mainly on groundwater for irrigation. This paper highlights a number of success stories, within the District, with respect to drought mitigation including the high adoption of modernised irrigation and drought tolerant barley seed. Preliminary research findings also provide an indication that for villages with a high percentage of irrigated land under modernised irrigation, there exists a lower difference in annual water table levels. Despite positive gains, there is concern that improvements in water productivity and efficiency may be offset by increasing land area under irrigation. Moreover, the combination of subsidised fuel and high indicative (state) prices for crops may limit the potential for water savings at the basin level. This of course has serious implications for both drought management planning and more so of the future viability of agriculture within the District. Given that water and land use decisions are inextricably linked, it is argued that coupling new farmer technologies within a sustainable land use management system is crucial to improving both on-farm efficiencies and encouraging the sustainable use of water.

**Key words:** Drought mitigation • Drought tolerant seed adoption • Groundwater monitoring • Modernised irrigation

### **INTRODUCTION**

Syria is considered a largely arid and semi arid country that ranks relatively low in human development indicators compared to its neighbouring countries [1]. Most families live in rural areas and depend mainly on agricultural and/or livestock production for their livelihood [2]. National level indicators for Syria hide a complex picture of poverty and insecurity found at the local level particularly in rural areas [3]. In particular, rural households that depend only on livestock production have been identified to be among the most vulnerable [4]. Many previous studies have highlighted a correlation between rural poverty, access to physical resources (owned land, water, animals) and agro-ecological variables (climate, irrigation water, soil) [3]. Coupled with the issue of resource endowments are the often overlooked agricultural and cultural practices that pervade. Land management systems applied in many areas of the world including the semi-arid areas are damaging soils and limiting their capacity to generate rising yields on a sustainable basis [5].

Droughts a common feature of the environment caused by low values of precipitation, invariably lead to steep declines in agricultural productivity throughout the region. However, within the semi arid areas and dry sub humid zones, agricultural droughts and dry spells are often caused by management induced water scarcity rather than absolute water scarcity and can easily be prevented through better on-farm water management [6]. The current focus of water management has created an 'artificial' divide between irrigated and rainfed agriculture. Thus there is a need to understand that irrigated agricultural systems generally depend in part on contributions from green water and investment in blue management options can reduce these shocks through improvements in rainfed agriculture which can in turn provide a set of management alternatives from fully rainfed systems to fully irrigated systems. (ibid).

In Syria, as for many other countries within the region, this has immense policy relevance given that inefficient water management and over-exploitation of the majority of basins has impacted on residents in these areas including causing significant out-migration [7].

The likelihood is that both precipitation changes combined with climate-change induced temperature rise will also increase the water requirements of crops in future years [8]. Thus, the urgency of providing adaptive development programs that address the issue of agricultural sustainability, whilst contributing to food security and climate-change adaptation has been well documented (ibid).

Whilst this paper deals solely with assessing technology options for agricultural drought mitigation or dry spells, it should be noted that other areas are equally interconnected and affected by drought specifically extended periods of drought years i.e. 'hydrological drought' or 'meteorological' drought. Moreover, mitigation strategies should also reflect the increasingly human impact that drought has not only on food security per se. For example, migration of households, in search for work or food in times of drought can also impact on school attendance for children and exacerbate certain health risks. This is often referred to as 'socio-economic' drought and highlights one example of why a socio-economic approach to drought mitigation is needed and one which takes a long-term view on sustaining livelihoods.

However, for the purpose of this paper three mitigation strategies that directly relate to agricultural drought episodes are discussed: (i) increasing the efficiency and productivity of irrigation water through adoption of modernised irrigation, (ii) groundwater monitoring and (iii) new drought tolerant barley adoption.

This paper aims to highlight some of the successes and lessons learned under each of the themes mentioned above using data gathered from monitoring activities and periodic evaluations supported by Aga Khan Foundation (AKF). It also aims to put each of these mitigation strategies within a broader policy context.

**Study Area:** Salamieh District is situated in the centre of Syria and covers approximately 5000 sq km with an estimated population of 241,000. It is characterized by low and erratic rainfall which is typically distributed unevenly over the growing season. Groundwater is the main source of irrigation water. The district is divided into 4 agro-ecological zones that are determined by rainfall (Figure 1). Zone 2, located in the east, is typically the wettest area with an average annual rainfall exceeding 300 mm. In contrast, Zone 3 is slightly drier ranging from 250 to 300 mm per year. Zone 4 is the marginal zone receiving between 200 and 250 mm of annual precipitation. Zone 5 is the badia (desert) and steppe zone receiving less than 200 mm of rainfall annually and is only suitable for rangeland grazing. The majority of the residents in the District are rural (65%) and the remainder peri-urban or urban (35%).

Both Zones 2 and 3 are typified by mixed crop/livestock production systems, as well as Zone 4 which has the heaviest crop-livestock interaction as animal populations are higher. Farmers in the dry margins play a key role in providing livestock products to expanding urban centers [9]. Thus, barley production and



Fig. 1: Salamieh District by administrative and agricultural zones

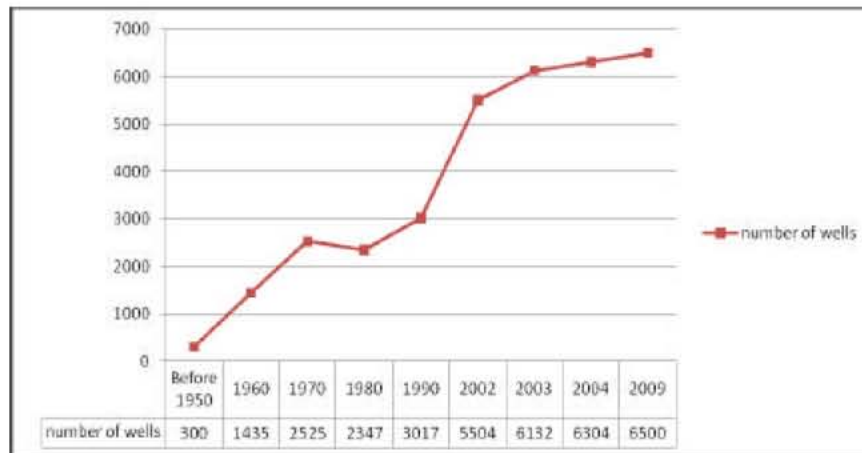


Fig. 2: Number of wells in Salamieh by year  
(Source: AKF 2010)

access to barley plays a critical role in the farming system within Syria and in Salamieh District more generally. The crop provides seed, an important ingredient in feed mixes and a joint product (straw) that is an important source of revenue to land holders who rent out their lands for grazing to sheep herders. Where farms are large and animal populations low, in Zones 2 and 3, barley may be grown as a cash crop with the stubble rented out for grazing by migrating flocks. [10]. In a favourable year, with adequate rainfall, some farmers are able to produce sufficient feed and fodder with the aim of building a reserve for the following year. However, for the most part, farmers attempt to maintain their herds owing to feed reserve (grazing residue, barley grain, stock) and purchase supplementary feed (in most instances barley grain).

The majority of cultivable land in the District is rainfed (100,174 hectares) [11]. Approximately 79% is planted under cereal crops and of this percentage, 80% is planted under barley. Full irrigation is practiced in the summer for the production of summer vegetables/fruit trees and supplemental irrigation is widely used on winter cereal crops (mainly wheat and barley). It should also be noted that pricing policies directly affect farmers crop mix decisions particularly with respect to irrigated wheat and barley (as a minimum price is set by the government for wheat). Overall irrigated farm land has decreased from 40,000 hectares in 1960 to approximately 9,000 hectares in 2007 (ibid). This has largely been due to a previous concentration on water intensive cotton production which was released in the 1960's and which resulted in a

decrease of functional wells. Of the approximate 6000 groundwater wells identified by AKF in 2003, almost 3,500 of these were dry. The reduction in the subsidy on fuel prices in Syria in 2008 (as a result the price of diesel quadrupled since 2008) has caused a dramatic increase in the pumping cost for irrigation water [12]. Despite this and legislation being introduced to prohibit the digging of new wells the number of wells has continued to rise (Figure 2).

**Overview of Existing Technological/Policy Measures:** Proponents argue that to ensure the longer term viability of agriculture in these regions and even more so to contribute to improvements in agriculture productivity per se; the use of new technologies couched within more sustainable production systems that improve the productivity of water are essential [13]. Furthermore, it is argued that substantial improvements to water productivity on can be made through the application of sound irrigation systems, rainwater harvesting, improved crop cultivars and appropriate cropping patterns (ibid)

In recent years, numerous crop varieties have been developed which are drought tolerant and mechanical irrigation systems such as drip irrigation have also been shown to significantly improve water efficiency. There is a wide consensus that drip irrigation and sprinkler systems have a high level of irrigation efficiency<sup>1</sup>. The level of irrigation efficiency for a sprinkler, drip system or pressurised irrigation technique is estimated to be between 80-94% where as it is much lower (35-40%) for

<sup>1</sup>Despite numerous definitions irrigation efficiency, broadly defined, relates to minimising the loss of water during conveyance. These efficiencies are expressed in percentage (%) terms with a maximum value of 100%. Anything below this is considered a loss during the process. They are mainly used for design purposes and are not necessarily linked to crop production.

traditional gravity (surface) irrigation, largely due to lower evaporation and seepage [1]. Other authors have shown the potential of drip irrigation to be of enormous benefit to developing country economies by stimulating net incomes among the rural poor through increased production and thereby contributing to improvements in household food security [15]. Despite this adoption of drip irrigation, throughout the world, is still very low. For example, in India and China between 1-3% of land is cultivated with drip irrigation and on roughly 4% in the United States [16].

Alongside improved irrigation systems and growing improved crop cultivars altering of tillage practices from tillage systems to low-till or even zero till as a method of improving soil moisture retention is another method to improve water productivity [17]. Conservation Agriculture (of which minimum soil disturbance is one component) has been found to result in a 30% water saving compared to conventional tillage based systems [18]. Additionally, there are other potential benefits as better infiltration rates of water into the soil, reduce run-off losses of excess water, provide replenishment of groundwater and a more steady flow of rivers and wells even in the dryer months of the year [19].

As with adoption of any new technologies there is much debate about the mode of transferability to the users and the appropriate political, social and institutional frameworks that would make the diffusion of such technologies successful. Some have noted that to get these technologies widely adopted particular emphasis on developing market incentives for farmers needs to occur. For a richer farmer this means equating a water price with the true social cost associated with extracting from groundwater or river-based irrigation [17], which would in turn spur the adoption of more water efficient technologies and cropping patterns. For, the poorest of the poor farmers, subsidies and grants that cover the initial cost of the technology have been proposed (ibid).

Other institutional mechanisms have been put forward such as the creation of Water User's Associations (WUA), where farmers organize locally within a defined area and are collectively responsible for providing and maintaining water for users. Some countries have adopted this fairly successfully. In Tunisia, for example where WUA's are responsible for both irrigation and residential supplies. [16]. Likewise, community recharge initiatives in India have successfully reversed falling water tables [20].

However, a number of problems exist with these institutional options particularly in countries such as Syria where groundwater is a "common property" and where pricing of water has been historically opposed and socially difficult to implement [6]. Moreover, governmental subsidies can also create artificially low water prices that encourage the over use of water. (ibid; 21). Although some countries have managed to curtail this by successfully proposing alternate cropping options and phase out more water intensive crops. For example, in Beijing, rice is being phased out and Egypt restricts rice in favour of wheat. Additionally, Israel which has been a pioneer in raising irrigation productivity is depleting both of its principal aquifers and has responded by banning the irrigation of wheat. [16].

The international development community through NGO's and international development organizations are able to play an important bridging role in helping to trial the suitability of these technologies and institutional options; thereby facilitating uptake in a variety of different contexts. However, in order to better aid community development, an understanding of the numerous trade-offs that exist with the uptake of new technologies, which can potentially be counter intuitive needs greater attention. Much has been written on this topic with regards to understanding trade-offs of agricultural programmes and the need for better impact assessments [22, 23].

## **MATERIALS AND METHODS**

This paper presents data from a number of sources. Groundwater monitoring data for 23 villages out of 172 villages within the District are presented for the years 2005 to 2008. This is based on a random sample of wells within each of the villages (120 wells across Salamieh District have been monitored in total) which have been measured on a quarterly basis in order to give an indication of the overall water levels within the villages.

Statistics on the proportion of irrigated land devoted to summer vegetables and fruit trees cultivated with drip irrigation have been gathered from the Ministry of Agriculture and are also presented for the 19 villages where well monitoring data is available.<sup>2</sup>

Secondly, a quantitative survey of barley farmers (an interim assessment) was conducted by AKF's Monitoring and Evaluation Unit in Salamieh, Syria in 2009.

<sup>2</sup>We are aware that the efficacy of this data may be questioned. Despite obvious shortcomings it provides a good reference point for the analysis conducted in this paper.

The interim assessment aimed to assess the extent of new barley variety adoption within the area where AKF had distributed seed over the period 2003-2009. A multistage stratified cluster design was used. A list of barley farmers in the specific project area (in this case 46 villages of the 126 villages where barley is grown in Salamieh District) were divided into three stratas relating to agricultural zone. Five clusters (i.e. villages) were chosen at random within each stratum and a random sample of 8 households per cluster were interviewed. 40 cases in total from each stratum were interviewed. The survey is not representative of the District as a whole as other farmers in the remaining villages where barley is grown were not included in the sampling frame.

## RESULTS AND DISCUSSION

**Improving Irrigation Water Efficiency and Groundwater Monitoring:** Table 1 shows the direct amount of land coverage of modernised irrigation for summer vegetables/ fruit trees and winter crop production. Much of the winter production in Salamieh District is still done so using conventional surface irrigation. In other parts of Syria, modernised sprinkler systems are usually used for full irrigation during the summer and then utilised for supplemental irrigation in the winter. Due to the 'occasional' use of the systems during the winter growing season the high capital investment cost often reduces uptake. Additionally, rainfed crops are cultivated on a large amount of land and therefore would require a large irrigation system [13].

Direct coverage refers to the amount of land area cultivated with modernised irrigation sets that have been disseminated by AKF. This has helped to speed up the government's initiative of increasing uptake of modernised irrigation. In 2006, the Ministries of Agriculture and Irrigation in Syria launched a new 10 year national irrigation modernisation project. In spite of interest free loan provisions for farmers and grants that

cover 30-40% of the cost of the networks, farmer uptake has been slow. Furthermore only 20% of the irrigated land in Syria is cultivated with modernised irrigation [25].

The following constraints which have limited the spread of modernised irrigation uptake in Syria have been cited (ibid):

- The individual costs to farmers are still very high.
- Many farmers are unable to acquire the low interest loans and grants from the government as it requires that land ownership has to be proven. This has proven to be challenging owing to issues around the current land cadastral system.
- As agricultural water is not priced, there is a lack of incentive to reduce water consumption and invest in costly techniques.
- Those that have adopted modernised irrigation often lack the information on proper installation and maintenance of such systems as there are very few qualified private irrigation engineers. In addition, government extension agents also have limited knowledge of modern irrigation systems. This results in inefficient systems often being used and also increases the costs in the long run for the farmer.

The focus thus far in Salamieh District by AKF has squarely been upon behavioural change, providing affordable and easily accessible loans (group/individual) and the provision of on-farm technical support. <sup>3</sup>Furthermore, AKF has helped to facilitate:

- Reduction in irrigation equipment costs (negotiated with the supplier due to the large purchase from a group).
- Small and manageable loans which do not require "collateral".<sup>4</sup>
- Technical support in designing, installing and operation/ maintenance for the irrigation networks.

Table 1 Modernised irrigation coverage by land area, period and type for Salamieh District

Period	Type of land use	Amount of overall land (hectares)*	Direct coverage (hectares)	Percentage (covered of overall land)
2003-2010	Summer vegetables and fruit trees	4,569	1,350	30
2008-2010	Winter crops	4,656	200	4

(Source: AKF 2010)

<sup>3</sup>Over the period 2003 to 2009, more than 110 group loans have been provided to farmers for the purchase of modernised irrigation equipment. Loans have been provided by the First Microfinance Bank in Syria an initiative of Aga Khan Agency for Microfinance (AKAM) a sister agency of Aga Khan Foundation.

<sup>4</sup>Collateral here is defined in the traditional sense i.e. tangible assets. In the case of group loans risk is spread as each borrower is a guarantor for the other.

Although there has been increasing coverage of modernised irrigation utilised for summer production, land for irrigated summer vegetables in Salamieh District has shown an increasingly upward trend and has more than doubled over the period 2003-2007 [26].

While there is evidence to support the contention that less water per unit of land is applied under drip irrigation than traditional forms of irrigation [14], some farmers may have used this to their advantage by increasing the amount of land area devoted to summer vegetable production. Thus although there are many positive spin-offs including increased production and lower water use per unit area, the long-term sustainability of water at a basin level may be in question. For example, as farmers take advantage of the higher productivity per unit of area of land by bringing new areas into cultivation this may not necessarily save water at a basin level as the total volume of irrigation water used may increase [27].

Additionally, recent research has highlighted with respect to state indicative pricing (the high prices for wheat in Syria), that this may induce more farmers to grow wheat and thereby use more water. Moreover, they further note that policies that support such high prices, for instance wheat and also low cost irrigation (fuel subsidies etc) encourage yield maximizing but with low water productivity [21].

**Groundwater Monitoring- Have Farm Efficiency Gains Been Mirrored at a Basin Scale?** Given irregular recharge rates and inconsistent pumping of groundwater for irrigation purposes, improving the monitoring of groundwater helps to both increase awareness of low water levels among communities and also examine measures that may reduce groundwater extraction.<sup>5</sup> It can also be useful in providing an insight into whether mitigation efforts such as modernised irrigation and governmental policies have proved useful in reducing groundwater extraction.

Although there is an argument that the reduction of subsidies (subsidised fuel for instance in the case of Syria) may adversely affect farmer welfare in the form of lower incomes and particularly poorer farmers, proponents have argued that the reduction or removal of such a subsidy will increase economic efficiency, reduce government spending and also improve environmental

quality. Furthermore, farmers incomes and profitability will eventually recover following an initial adjustment period [28].

If such agricultural policy decisions continue this may curtail the amount of overall irrigation water use (particularly as water gets scarcer) and may also cause farmers to alter their cropping mixes in order to allocate water more efficiently i.e. to those crops that are less water intensive. The higher irrigation costs incurred by farmers may also induce an increase in farmers switching to modernised irrigation. For example, [29] showed in several fuel-cost scenarios for five villages in four stability zones in Aleppo (Syria) that agricultural policies that sustained low irrigation costs resulted in farmers over-irrigating largely due to both high intensity of well drilling and expanding their land under irrigation. However, as availability of water grew scarcer farmers reduced the area for high water consuming crops because of the increase in production costs.

This being said although the reduction in subsidised inputs may well have influenced farmers to adopt modernised irrigation by increasing the value of irrigation water; it may not have had an effect on overall water use in areas where water availability is high. For example, previous research has examined the effects of well depth and land quality on farmers choice of irrigation system [30]. Their findings highlighted that adoption of modern irrigation technologies (drip or sprinkler systems) was more likely in locations with expensive water (deep wells) and low land quality where as traditional surface irrigation was associated with better land quality and cheaper water. In this case, another likely explanation could be the fact that agricultural policy decisions (i.e. reduction in subsidised fuel in the case of Syria) may have differential impacts on pumping patterns dependent on availability of water and recharge rates.

Thus considering that drought episodes are likely to intensify and precipitation declines also a possibility, the possible expansion of irrigated area and unregulated well drilling may increase the overall volume of water being used and compromise the sustainability of water within the District for future generations. These concerns necessitate the importance of trying to ascertain whether on-farm gains in efficiency have been mirrored at the basin level.

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<sup>5</sup>The overall management of groundwater as a common property resource would require a systematic approach at the watershed or basin level and the feasibility of such an approach is dependent upon the political will and appetite to consider moving in such a direction.

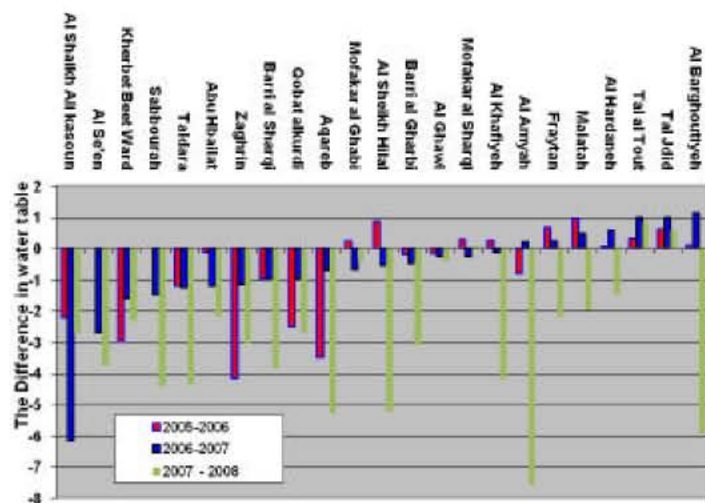


Fig. 3: Difference in water table depth 2005-2008 for 23 villages in Salamieh District

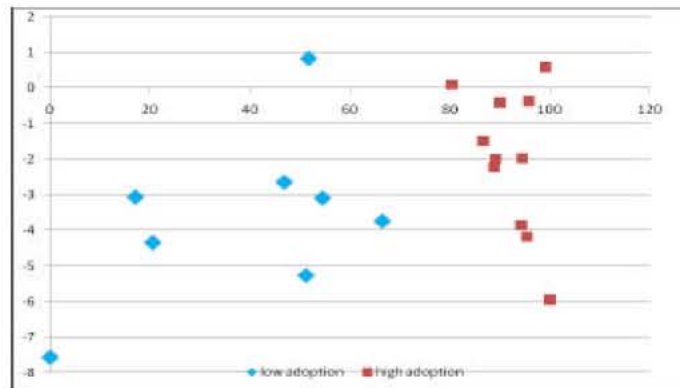


Fig. 4: Scatter plot of difference in water table depth (in metres on the vertical axis) against percentage of land under modernised irrigation (shown by the horizontal axis) during the 2007/08 season for 19 villages in Salamieh District

Figure 3 shows the water table depth difference across 23 villages in Salamieh District from 2005 to 2008. It is an important indicator of the water balance/availability within an area. The balance is positive when the amount of water consumed in irrigation is less than the amount recharged. Figures above 0 on the graph indicate a positive overall difference and positive water table and those under 0 signal a negative difference and overall negative water table<sup>6</sup>.

Figure 3 shows the overall trend over 2005 - 2006 and 2006 - 2007 for a number of villages has been positive in terms of the difference in their water table (above 0 and higher than the previous year). For example, Tal Jaded and Tal tout. However, from the period 2006 -2007 to 2007-2008 almost all villages have seen a negative difference in the water table (reduction in the water table). This highly relates to the lack of recharge for that year as 2007-2008

was a drought year with a much lower annual average in rainfall within Salamieh District. Thus this caused an increase in the depth of the water table as farmers had to dig deeper to get water.

Despite this and in using a drought year as an example where a negative water table is found in almost all villages, a 'crude' proxy indicator for the success of mass modernised irrigation adoption is shown in Figure 4.

Figure 4 shows the percentage of land under drip irrigation for summer crops and fruit trees for each village plotted against the difference in water table depth for each village where water table measurements have been gathered over 2007/08. Although there is some notable variability there exists a high concentration of villages that have a higher percentage of land under modernised irrigation and a lower difference in the water table from 2007 to 2008 (See villages highlighted in red).

<sup>6</sup>These villages are not representative of the entire basin and are only a sub sample of villages where both land under modernised irrigation and groundwater monitoring data were available.

Table 2: Difference in depth of the water table for selected villages in Salamieh District with low and high adoption of modernised irrigation for 2007/2008

	Subgroup mean water table depth difference (metres) 2007/2008	Subgroup (SD)	Subgroup (N)	mean difference	95% confidence interval
Low adoption	-3.6	2.39	8	-0.92	-3 to -4
High adoption	-2	2	11	0.67	-1.6 to -2.4
Overall mean		Overall SD	Total (N)		
	-2.67	-2.25	19		

\*not significant at 0.05 level

Thus it is interesting to note that over 2007 to 2008 although there was an overall reduction in the water table depth in most villages the difference is much lower in those with a higher adoption of drip irrigation.

Table 2 shows the mean difference in water table depth over 2007 to 2008 for those villages grouped under low modernised irrigation adoption and high modernised irrigation adoption.<sup>7</sup>

The results show that the mean depth in water table depth is -3.6 which is 1.6 metres, on average, higher than for those villages with a higher proportion of their irrigated land under modernised irrigation (-2). The difference from the mean also indicates that for those with high adoption there exists a 0.67 lower overall difference in water table compared to the mean of both groups. Conversely, villages with a lower overall amount of land under modernised irrigation have a -0.92 higher mean difference in water table depth than the mean. The higher SD value also shows there is high variability within the low adoption group. Although the means were not statistically different ( $t(17) p=0.13, >0.05$ ) a larger sample size and time period under consideration may have aided.<sup>8</sup>

It may, however, be possible to garner some insight from this for other areas, particularly for other water deficit basins and areas where water quality/availability has significantly declined. For example, high adoption of modernised irrigation may actually help to reduce the rate of further depletion and more so in particularly dry years when water availability is very low. Of course an understanding that modernised irrigation adoption alone is not a panacea for water conservation at a basin level should be understood given the trade-offs.

**Drought Tolerant Barley Seed Dissemination:** Adoption of new seed varieties in Syria as in other dry areas has

been much slower than more favourable climates due in part to the difficulty in breeding seeds that respond to such variability. With the high probability of getting low yields particularly in drier zones, farmers are discouraged from purchasing expensive new seed and this does not provide the formal sector an incentive to produce and supply large quantities of new barley varieties [31]. Field experiments have indicated that new barley varieties can provide up to 20% greater yields without the need for additional inputs, however, uptake has been slow (ibid). Three varieties of new seed were distributed by AKF since the 2003/2004 growing season. Over the period 2003/2004 to 2008/2009, 900 farmers in 46 villages in Salamieh District were distributed with 100kg of seed at cost price.

Results showed that the proportion of land under the new variety is higher for irrigated lands than for rainfed. More than half of the irrigated land (53%), of those surveyed, is cultivated with the new barley variety compared to the local variety. In Zones 2 and 3 it is especially high, however, in Zone 4 the local variety still covers the majority of the irrigated land (61%).

In contrast, for rainfed farming, the local variety is still widely used and has the highest proportion (78%) of the land cover, on average compared to the new variety which covers 22% (Table 3).

The results do provide an indication that in Zone 4, in particular, where the ramifications of drought are likely to be more severe (i.e. on feed availability and livestock) other alternative seeds need to be sought that may be more suitable given the low degree of adoption.<sup>9</sup> Moreover, new seed varieties need to be suitably tailored to the specific agro-ecological zone and failure in doing so can increase levels of poverty if inappropriate varieties are adopted [32].

<sup>7</sup>High (above 70%) and low (below 70%) refer to the percentage of land under drip irrigation from the total irrigated area per village. Of course it is understood that other factors including location, land use adoption time and rainfall all affect the water table. For the difference in water table depth, a drought year is used where most of the villages have a negative water table.

<sup>8</sup>Although, the Pearson correlation coefficient = 0.44 for the two variables it shows a medium to positive relationship between land under modernised irrigation and water table depth the t test did not show significant differences between water table depth levels for the two groups identified.

<sup>9</sup>The majority of farmers in Zone 4 found that the straw produced from the new variety was not as readily accepted by the sheep as the local variety.

Table 3: Proportion (%) of total cultivated area (dunums) with barley under new/local varieties by irrigated/rainfed and zone in 2009

	Zone 2		Zone 3		Zone 4		Total	
	New	Local	New	Local	New	Local	New	Local
Irrigated	74	26	67	33	39	61	53	47
Rainfed	19	81	32	68	12	88	22	78
Total cultivated area irrigated (dunums)	327		345		763		1,435	
Total cultivated area rainfed (dunums)	2,123		4,753		3,988		10,864	

Note: 10 dunums= 1 hectare

Table 4: Frequency and percentage of adopters/new growers of new barley varieties by zone in 2009

	Number of adopters	New Growers	Total Number of New barley variety growers	Total N
Zone 2	21	7	28	44
Zone 3	15	15	30	48
Zone 4	11	7	18	40
Total	47	29	76	132

\*Note adopter is defined as a farmer using seed for two or more years

Table 4 shows the percentage of adopters of the new barley varieties for both irrigated and rainfed land. It provides a better indication as to the suitability of a variety as it assesses over time how many years a farmer has been using it [31]. Growers were divided into two types: ‘new growers’ who grew the variety for the first time and ‘adopters’ who grew the variety more than once (i.e. 2 years or more).

There are some complexities in using the degree of adoption as an indicator to measure the success of a new agricultural technology in marginal environments given that in a drought year farmers contract the amount of cultivable land and may not even plant altogether given that rainfall may not be sufficient enough to provide even minimal yields. However, particularly in drier zones if drought tolerant barley seeds are able to perform even a margin better than local varieties this can have a significant impact on potential grazing availability for that year and limit the adverse effects to livestock. Furthermore, improved productivity of new varieties compared to local on irrigated land may also provide a buffer against periodic drought.

## CONCLUSION

This paper has highlighted a number of success stories in the field of drought mitigation within the Salamieh District namely;

- A high degree of adoption of modernised irrigation throughout the District with land owing to irrigated summer vegetables and fruit trees.

- Groundwater monitoring that has helped to improve understanding of pumping patterns within the District and provide an indication of the impact of drip irrigation on water table levels in a select number of villages.
- A high rate of drought tolerant barley seed adoption by farmers within select villages compared to local seed variety usage, albeit, still fairly low on rainfed land particularly in the drier agricultural zone (Zone 4).

A number of trade-offs have also been presented that will undoubtedly shape future adaptation options for drought mitigation particularly in areas where water is becoming scarcer. These include the need for groundwater monitoring that may help to determine particular cropping mixes for certain interlinked areas within the basin based on their availability of water. This will be augmented by future advancements in agricultural research e.g. improved agricultural practices and systems. Thus as there is an indication of both the harmful long-term effects of inappropriate land management practices coupled with potential over-use of water; one method of mitigating the effects of such actions is by coupling new technologies in a sustainable land use system such as conservation agriculture. This has been shown to improve both productivity and water savings at the farm level, which have resulted in further benefits such as positive replenishment of groundwater [18].

However, equal adaptations to legislation or government policy that will reflect areas where water

availability is likely to further decline will be a priority if such technologies and systems are to be effective. Exploring options such as cropping restrictions, enforcement of legislation on new well drilling and or the altering of price support systems to name a few.

As drought episodes become more frequent and the intensity of these “shocks” ever more severe; both from a hydrological perspective and increasingly a socio-economic one, mitigation strategies will also have to reflect this. Thus, although agricultural sustainability will be important, it cannot be dealt with in isolation and incorporating a multitude of actors/programmes that will focus on ‘human capital’ (e.g. education/health; off-farm job creation) will enhance a community’s ability to adapt to a rapidly changing climate and thereby seek opportunities for the future.

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