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More from less: policy options and farmer choice under water scarcity

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Abstract. In much of the world, fresh water is scarce and getting scarcer. Growing populations, increasing industrialisation, and environmental concerns have all put pressure on the water consumed by agriculture. This paper addresses the economic consequences of a permanent reduction in canal water for irrigation. Using detailed cost-of-cultivation data from the Gediz Basin, Turkey, the key questions are: How can farmers best respond to reduced surface water supplies? How can the canal management authorities best distribute this limited water? And, can the demand for water be reduced through input and output price policy? These questions are answered with scenario comparisons under several water availability, crop pattern, price and investment assumptions, for the short and medium time horizons.

Keeping productivity high and water use low requires coordination between farmers and the water management authorities. The analysis shows that, in this region, farmers should keep all their land irrigated at lower yield levels, rather than reduce their cropped areas. The canal managers should opt for a short irrigation season, rather than an extended season with long dry intervals. Sensitivity analysis on a range of prices indicates that crop, rather than water prices, affect the efficiency of water use. The scenarios are evaluated using AGWAT, a spreadsheet-based farm-budget program which is simple and widely applicable. The range of policy choices considered establishes a framework of analysis for other, potentially water-short basins, beyond the Gediz or Turkey.

Key words: water scarcity, irrigation management, Gediz Basin, Turkey

Introduction

In most of the Near East, fresh water is scarce and getting scarcer. Growing rural and urban populations, higher cultivation intensities, increasing industrialisation, and, of late, environmental concerns, have all combined to put pressure on every country's internal renewable water resources (FAO 1997). Irrigation is by far the largest consumer of fresh water, so should the water availability tighten in the near future, transfers from the agricultural sector are very likely. But maintaining the stability of farm incomes and raising crop yields are among the basic principles of agricultural policy in newlyindustrialising countries. This paper explores the short-term and longer-term options that farmers have to protect their incomes if their surface irrigation supplies are significantly and permanently reduced.

The specific study area for this paper is the Gediz River Basin in the Aegean agricultural region of western Turkey. Using detailed cost-of-cultivation data from six canal irrigated villages, the following questions are addressed:
(1) How can farmers best respond to a future canal water shortfall of 25% or more? Like many other OECD (Organisation for Economic Cooperation and Development) countries, Turkey subsidizes farm inputs and supports farm outputs, through a system of direct payments and some border controls. Therefore:
(2) Is it possible to reduce the demand for irrigation water through alternative input and output price regimes? Finally, given that managing and distributing any shortage will be the responsibility of the DSİ (*Devlet Su İşleri*, or State Hydraulics Works):
(3) How can the DSİ ration the reduced water by month and by area, so the scarce water is used most efficiently?

The paper first gives an overview of the salient features of agriculture and water use in the Gediz Basin. It describes the six study villages, the data and the analytical method used. Briefly, the methodology is one of scenario comparisons under various water availability, crop pattern and price assumptions, using the type of data that is routinely collected by agricultural universities and ministries. Various scenarios under which the DSİ forces farmers to make do with less canal water are then presented. The analysis shows that how the cuts are distributed is at least as important as the magnitude of the cuts. It is also possible for farmers voluntarily to reduce their irrigation demand in response to different price policies – whether of water, energy or crops. These scenario comparisons indicate that the prices of water and energy, within feasible ranges, are too low to affect water use. The final section presents a summary of the main results.

The Gediz farmers who will have to adjust to potential water supply reductions are heavily dependent on irrigated cotton. Irrigated cotton is widespread in the water-short Near and Middle East, for instance in Iran, Iraq and Egypt. The response to reduced irrigation supplies in this part of Turkey is therefore of interest over a much wider geographical area.

Agriculture in the Gediz Basin[1]

The Gediz River flows west through the provinces of Manisa and İzmir and into the Aegean Sea just north of İzmir city. Most of the main valley and delta is irrigated. The typical farm is family owned and operated, with temporary in-migration of labour for the cotton crop. The majority of the farmers specialise in producing one or two commodities for the market, rather than food for home consumption. Most of their income is from agriculture. The average holding size remains small, especially by OECD standards. The 1990 Census shows that 85% of the holdings in Turkey were under 10 ha., and that 57% of these were fragmented into four or more non-contiguous plots (Agricultural Census, State Institute of Statistics. Ankara 1990). The area surveyed for this study conformed to this pattern.

The prosperity of agriculture in this valley is dependent on irrigation, primarily from surface water. Irrigation water releases from the multipurpose Demirköprü reservoir are managed by the DSİ, but, in 1995, the field level operation, maintenance, and record-keeping were turned over to 13 Irrigation Associations. During a severe drought from 1989 to 1993, the DSİ shortened the irrigation season to July and August only. This guaranteed the viability of cotton, the predominant crop of the area, and ensured reasonable, though sub-optimal, yields for grapes. After 1993 the canal water availability has steadily improved, so the “normal” irrigation season goes from mid-June to late September.

In the Gediz Basin, municipal and industrial water use are rising, but are still small relative to agricultural use. The city of İzmir pipes water out of the basin – its current rate of extraction is 20% of the total surface water used for irrigation (Murray-Rust et al. 1999). İzmir’s rapidly increasing water use has already lowered water tables in the delta area, which has allowed saltwater intrusions into cropped lands (Topraksu 1981).

The data and methodology

From July to November 1998, data on cropping patterns, irrigation practices, input use and yields were collected from six villages on the Gediz Basin. Three of these – Çapaklı, Eldelek and Pazarköy – are irrigated by the Salihli Right Bank (SRB) canal system. The majority of the farmers here have individual or shared wells, between 75 to 130 m deep, as a supplement or backup to their surface supplies. The other three villages – Çavuşköy, Kesikköy and Maltepe – are fed by the Menemen Left Bank (MLB) canal system. This is the tail-end of the Gediz Basin, so it has salinity and groundwater quality problems. Few farmers have access to clean groundwater, at whatever depth, or to electricity for pumping it out.

The crops included in the survey were cotton, grapes, fruit trees (represented by peaches), maize (both for feed and seed), watermelons and spinach (representing the short winter vegetable season). Together they covered over 90% of the irrigated area in the sample villages.

These data produced a profile of an "average" farmer, separately for each village and given the present water supply. Each case has the representative farmer's landholding (always 40 dekars, or 4 ha), his crop pattern, input use, canal water applications, well water use (if there is a well), the prices of all the inputs and outputs (in 1997 Turkish Lira), and yields.[2] For each village, the modal responses were used for the data, because the farmers reported similar cultivation practices and input use for each crop. Across-village yield and irrigation frequency variations were largely explained by soil types and the presence or absence of groundwater.

All the input, price and yield data were formatted in AGWAT (Perry 1997). AGWAT is an Excel spreadsheet which calculates gross and net revenues for selected farm types, as well as returns to labour and water. AGWAT computes indicative crop and farm budgets for a "normal" year, for the crop choices, yields, and input use levels specified by the analyst. It is not designed to optimise the farmer's land and water allocation. Therefore when the surface water supplies are reduced, or the relative prices are altered, the program will allow a comparison of all the possible scenarios. It will not automatically re-compute the farmer's best response.

There are two advantages to using a program such as AGWAT, as compared to models containing optimising routines. First, the Gediz Basin is a region of very varied cropping patterns, where even small farmers plant four or five crops each, because of varying soil types, labour availability, local market and export market conditions. Traditional optimising models using linear programming rarely yield such a wide range of crops in their single-farm solutions. Secondly, a grower's response to reduced surface supplies is multidimensional. In the short term, he might trade off reduced yields against reduced acreage, or eliminate crops with the lowest returns to water, or take poor quality land out of production. Evidence from the 1989 drought in western Turkey, and from western USA, indicates that farmers do all of these (Zilberman et al. 1992). Again, programming models would choose a "best" response. But for this analysis, it is more interesting to model a number of short- and long-term scenarios, and to compare their net and gross returns. This way, both the farmer and DSİ can be presented with the full range of options, and their economic impacts, in the eventuality of permanent water shortfalls.

Table 1 describes the "base case" to which different water supply and relative price scenarios can be compared. It shows the main characteristics of each village, and the returns to the farm under the present water supply conditions. The villages are arranged by location, from upstream to downstream. Both gross returns and net profits for the 4 ha farm are reported in (millions of) 1997 Turkish Lira. Net profits (gross returns minus variable costs) are the best

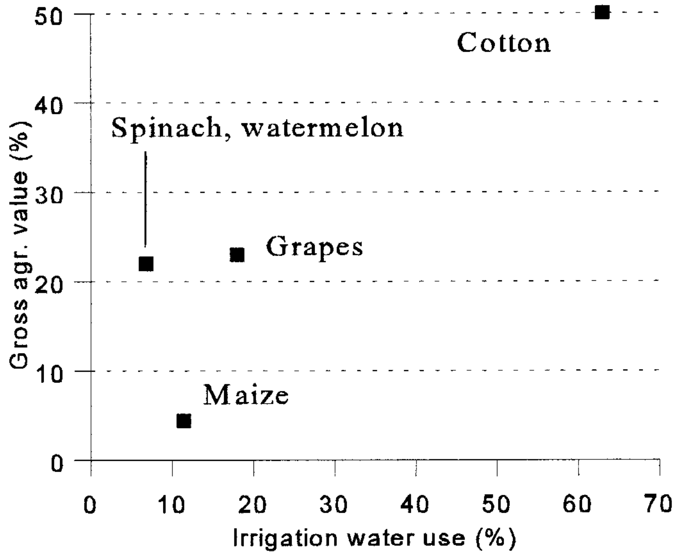

Figure 1. Water use and gross agricultural value, Çavuşköy.

measure of the farmer's own welfare. Gross farm income is a better measure of the farmer's contribution to the economy, especially when agricultural inputs do not have significant alternative uses. The returns to water indicate how productively water is being used for each crop, given the current price regime. The final column calculates the total irrigation demand (measured at the crop level) for the farm, from canal and well water.[3] It should be noted that this irrigation demand calculation has taken account of effective rainfall, but not water use from capillary rise or stored soil moisture. Therefore it may overestimate a farm's true irrigation requirement (Droogers et al. 1998; Molden 1997).

It is clear from the table that there are significant differences in the productivity of irrigation water for different crops.[4] Figure 1 plots the percentage of gross agricultural value contributed by each crop, against its share of the total irrigation water used in Çavuşköy, the head-end village of the tail-end system. At the bottom end, 11.4% of the total water is used by the feed maize crop, for only 4.4% of the gross agricultural value. At the high end, 6.8% of the irrigation water is given to spinach and melons, which produce 22% of the value. Cotton, the dominant crop of MLB, shows relatively low returns, using 62% of the irrigation water but contributing under 50% of the gross value.

It is not feasible for the agriculture of Menemen Left Bank abruptly to switch from cotton to watermelons and vegetables. The graph serves to indic-

Table 1. The “base case” characteristics for a 4 ha farm in the six study villages.

Village	Crop pattern (%)	Yield (T/ha)	Returns in TLM/’000 m^3	Net profit (TLM)	Gross returns (TLM)	Irrigation demand: ’000 m^3
Çapaklı (SRB) (wells; diesel pumps)	Cotton: 50	4	115	2849	3426	20.2
	Grape: 30	5	174			
	Maize: 10	4	116			
	Fruit: 10	15	165			
Eldelek (SRB) (wells; electric motors)	Cotton: 55	4	115	2813	3470	19.6
	Grape: 30	5.5	194			
	Maize: 10	9	77			
	Wheat: 10	6	145			
	Fruit: 5	15	165			
Pazarköy (SRB) (wells; boron-affected water)	Cotton: 90	4	110	2110	2764	17.9
	Grape: 10	5	173			
Çavuşköy (MLB) (some groundwater)	Cotton: 60	4	85	2671	3098	22.5
	Grape: 20	4	141			
	Maize: 10	8.5	49			
	Melon: 10	5	241			
	Spinach: 5	15	2980			
Kesikköy (MLB) (only canal water)	Cotton: 80	4.25	89	2068	2536	20.7
	Wheat: 10	6	272			
	Melon: 10	5	241			
Maltepe (MLB) (only canal; salinity; heavy soils)	Cotton: 90	4	85	1872	2424	22
	Wheat: 10	6	272			

The yield figures are village-specific averages in a normal water availability year, as reported by the farmers. The net and gross returns are reported in millions of Turkish Lira. In 1997, US $1 = 200,000 TL approximately. The irrigation demand is measured at the crop level, for a 4 ha farm, using CROPWAT (Smith 1992). The cropping patterns are for the year, not one growing season, so the cropping intensity is higher than 100% for some villages.

ate which crops could be reduced (or eliminated) at lower cost to the economy if less irrigation water is available.

Reducing the water supply

Table 1 represents the current practice in the six surveyed villages, with crop mixes which are location-appropriate and have evolved over time. The individual crops are assumed not to be under water stress, as the irrigation supply was generally adequate during the study period. However, at some future date, there could be a permanent 25% reduction in canal water supplies for irrigation, on account of increasing pollution, increasing competition, or both. The responses of the farmer and of the DSİ, in the short run and over a longer period, collectively provide a framework for assessing the cost of this reduction. These responses are obviously more constrained in the short run.

The short-term choices

The DSİ, faced with the need to distribute 25% less water to the same number of irrigators, has two choices. It can retain the current irrigation season (June to September), but deliver less water to each Irrigation Association during each watering turn. Without supplemental groundwater, the crops will be somewhat stressed at all times. Alternatively, the DSİ can shorten the irrigation season to July and August only, providing complete irrigations for these months and none at all during the rest of the year.

Depending on the irrigation schedule, farmers adjust their crop mixes so their net incomes suffer the smallest losses. They can fully irrigate a smaller crop area, eliminating crops with poor returns to water, leaving some land fallow, and perhaps adjusting their crop mix.[5] This option is feasible only for annual crops, and only for the extended irrigation season. Alternatively, they can keep their original crop mix and accept lower yields. This option is feasible both for the normal and shortened irrigation seasons.

For the six villages, there are now a total of 18 short-term “shortage scenarios”. Each village has 2 delivery schedules (normal or shortened), and, within the normal schedule, the farmer has 2 responses (reduced acreage or reduced yields). The yield reductions, which have to be computed outside AGWAT, are not the same under the two irrigation deliveries. In the extended period, the DSİ makes proportional cuts every month. The resulting lower yields can be calculated for any relative shortfall from FAO Irrigation and Drainage Papers no. 33 (Doorenbos & Kassam 1979), which expresses the relative yields of crops as a function of the evapotranspiration deficit. This is how the yields corresponding to the 25% supply reduction, spread over

June to September, were obtained. But for the shortened delivery option, the methodology of FAO 33 is not appropriate. To derive the likely impact of a shortfall at every growth stage of the plant, Doorenbos and Kassam ask: what is the impact of water stress during this stage, if the crop is not stressed at any other stage? For the July and August irrigation schedule, this is not the relevant question. Rather, it is: what is the impact of withholding water from every stage except the most critical one? Therefore the likely yields in this second scenario were averaged from farmer responses, based on their experiences with the short season for most of the 1990's.

With repeated runs of AGWAT, new budgets were computed for the sample 4 ha farm, as well as the per-crop returns to water and to land. In these modified models, the groundwater capacity was made lower to account for the now lower recharge. Where the crop mix changed, but yields remained high, there was no need to adjust any input use data. However, for the scenarios where yields were lowered, the monthly crop water "requirements" were adjusted downwards. The monthly labour requirements for harvesting and transport were also lowered. No other changes were made, which means that the models have not taken into account any interaction effects between water, labour and fertilisers (Bernardo et al. 1987).

The discussion of the scenario results is confined to three of the six villages – Eldelek, Çavuşköy and Kesikköy. Eldelek has wells which can fully make up a 25% canal water shortfall, so there are no changes in crop mix or yields to report.[6] Çavuşköy (Table 2) has limited pumping capacity, and Kesikköy (Table 3) is completely canal-dependent.

For each water delivery schedule, for each farmer response, Tables 2 and 3 report the two yield-crop pattern scenarios which give the highest net returns to the farm. (For most of the scenario solutions, there was no conflict between net and gross returns). The results show that, when water is limited, the shorter irrigation season is both more profitable and less water-consuming. Cotton dominates in MLB, and, with the full irrigation requirement met in July and August, yields hardly suffer at all. The marginal value of the water applied to cotton outside July and August appears to be quite low. Indeed the AGWAT solutions for Menemen reveal that cotton irrigated for its maximum yield returns between 85 and 89 TLM/'000 m^3. With only July and August irrigations, it returns between 115 and 125 TLM/'000 m^3.

It should be noted that none of the more profitable scenarios for Menemen contains feed maize. With maize, the returns are always lower. During the field surveys, farmers said that they liked maize to "give the soil a break from cotton", or to diversify their crops, or to feed their animals. While these may be good reasons to choose maize, its cost in terms of water, especially with limited supplies, is very high.

Table 2. Short-term responses to less water, Çavuşköy.

Irrigation schedule	Farmer response 1: lower acreage, maximum yields	Farmer response 2: maximum acres, low yields
June to September	1. Cotton 48%, grape 20%, w'melon 10%, spinach 5%; Cropped area 83%;	1. Cotton 60%, grape 20%, maize 10%, w'melon 10%, spinach 5%;
(25% cutbacks in every month; original net farm income 2671 TLM)	Net farm income 2326 TLM; Gross farm income 2655 TLM.	Net farm income 2294 TLM; Gross farm income 2688 TLM.
	2. Cotton 43%, grape 20%, wheat 15%, w'melon 10%, spinach 5%;	2. Cotton 65%, grape 20%, w'melon 15%, spinach 5%;
	Cropped area 93%;	Net farm income 2388 TLM; Gross farm income 2796 TLM.
	Net farm income 2398 TLM; Gross farm income 2707 TLM.	(Yields: cotton 3.4 T/ha; grapes 3.5 T/ha)
July and August	Not applicable	1. Cotton 60%, grape 20%, maize 10%, w'melon 10%, spinach 5%;
(Full water requirements given for 2 months; original net farm income 2671 TLM)		Net farm income 2496 TLM; Gross farm income 2888 TLM.
		2. Cotton 70%, grape 20%, w'melon 10%, spinach 5%;
		Net farm income 2582 TLM; Gross farm income 3032 TLM.
		(Yields: cotton 3.75 T/ha; grapes 3.6 T/ha)

The medium-term choices

Given a longer response time, both the farmers and the canal management authorities can make more significant changes. The farmers can dig wells and practise conjunctive irrigation, they can switch to more drought-resistant

Table 3. Short-term responses to less water, Kesikköy.

Irrigation schedule	Farmer response 1: lower acreage, maximum yields	Farmer response 2: maximum acres, low yields
June to September (25% cutbacks in every month; original net farm income 2068 TLM)	1. Cotton 65%, wheat 20%; Cropped area 85%; Net farm income 1650 TLM; Gross farm income 2008 TLM.	1. Cotton 80%, wheat 10%, w'melon 10%; Net farm income 1597 TLM; Gross farm income 1998 TLM.
	2. Cotton 60%, wheat 15%; w'melon 10%; Cropped area 85%; Net farm income 1732 TLM; Gross farm income 2052 TLM.	2. Cotton 70%, wheat 20%, w'melon 10%; Net farm income 1540 TLM; Gross farm income 1888 TLM.
		(Cotton yield: 3.36 T/ha)
July and August (Full water requirements given for 2 months; original net farm income 2068 TLM)	Not applicable	Cotton 80%, wheat 10%, w'melon 10%; Net farm income 1763 TLM; Gross farm income 2184 TLM.
		(Cotton yield: 3.75 T/ha)

crops, they can irrigate more efficiently using drip and sprinkler technology. The canal authorities have the choice of taking poor quality lands out of production altogether, and concentrating the water supply where its productivity is higher.

In the prolonged drought which hit the Gediz in 1989, the farmers did sink a large number of wells. Most of these were shared wells among 6–8 farmers. As one farmer said: “At that time, you had to join a well group. If you didn’t have money, you sold your household goods, you borrowed, you did anything. But you joined a group”. There has also been a move out of cotton into grapes, again more in Salihli than in the lower delta. Farmers using drip irrigation are still a minority in this basin, so enough data were not available to relate drip technology to yields. In this section the AGWAT models are modified to ask whether or not it is rational for farmers to invest in wells, and in vines, as a response to water scarcity. The profitability of water diversions within the

Table 4. Internal rate of return to wells in Salihli.

Village	Investment cost (1997 prices)	Net TLM, no well	Net TLM, with well	IRR
Eldelek	4848 TLM	2192	2813	11%
Çapaklı	4368 TLM	2167	2849	14%

Gediz command are also analysed, though inter-area reallocation is not under consideration at present.

Digging wells

Wells are already common in Çapaklı, Eldelek and Pazarköy. (They are not as widespread in Menemen Left Bank, primarily because the groundwater is deep, saline and boron-affected). If there is enough canal water, farmers often prefer it because it is cleaner and warmer. The wells are used for convenience, as a backup in case the irrigation season starts late, or for crops which need a pre-emergence watering. In 1998 the prices of canal water in SRB went up to 4 TLM per hectare per irrigation. Since then, the reliance on wells has gone up slightly. Well water is also used for vegetables and maize which need water more often than the canal can provide. Some farmers opt out of the DSİ-determined canal schedule, and irrigate from wells exclusively.

For a 25% reduction in canal supplies, distributed for full irrigation in July and August, the internal rate of return (IRR) to a well in Eldelek or Çapaklı is a straightforward calculation. The Eldelek well is electricity-operated, but the one in Çapaklı runs on diesel fuel. In this calculation, it is assumed that, without wells, the cropping pattern would not have included fruit trees. More cotton would have been planted instead. The yields of all the crops except wheat are lower without wells than with them. It is assumed that the farmer invests in a very expensive well and pumpset – in this example the well is 130 m deep, shared by 6 farmers and fitted with a 27 m deep submerged pump. The average well would cost less, especially where the water table is higher. All the investment costs are fully paid up in the first year. Table 4 shows the IRR to such a well for the hypothetical shortage scenario. The upfront investment costs, though high, are of the same order of magnitude as other investments such as tractors and tillers. The net income figures are for the sample 4 ha farm, from the year after investment. The IRR has been calculated for a 20 year period.

A real rate of return of 11–14% is very good in a country where the farmer can borrow money at zero to negative rates of interest. Had the shortfall been even more severe, allowing only a partial irrigation in July and August, the IRR would have gone up to 18% for both Eldelek and Çapaklı.

At the current (and generally adequate) levels of canal water availability, farmers who irrigate conjunctively may use their wells only twice a year. The IRR to a well in Eldelek without the hypothesised supply reduction would have been lower. But such a calculation, using expected values in an "average" year, would not take into account the option value of a well. Even in a normal irrigation year, the well gives the farmer security and flexibility, whether or not he uses it.

In the longer run, it is not clear that wells can continue to protect farmers against canal supply reductions. Even a moderate reduction will bring down the water table over time, and the pace of withdrawal could increase if more farmers dig wells. The rate of well use projected in this analysis may not be indefinitely sustainable.

Growing more grapes

In the short-term scenarios tested, modest and feasible crop mix changes were made to allow the farmer to adjust to smaller water supplies. For the longer term, farmers can switch to more drought-resistant perennial crops. Before the drought period, the cropping pattern for the Gediz Basin was overwhelmingly cotton. Data from the DSİ show that, since the drought, farmers in the upper and main valley now have 50% or more of the area under grapes. Indeed, during the field study period, new vines were still coming up – especially in Pazarköy.

There could be several reasons for farmers to have changed their crop mix – a water supply constraint is only one possibility. Favourable relative prices, access to new markets, crop rotation and crop diversification are also possible reasons. Grapes do not need less water than cotton overall, but they need it over a more extended period. The July–August season, when cotton's water demand is at its peak, is less critical for grapes. Grapes also have a rooting depth of up to 200 cm, so they can withstand periods of dryness and better utilise winter rainfall.

On the other hand, grape prices and yields have been rising steadily in the Aegean region. Turkey's exports of seedless raisins, for which the grapes are used, have grown dramatically since the 1980's. Figure 2 shows the price indices for cotton and grapes from 1987 to 1997, starting from a base price of 100 for both.[7] Grape prices appear to have risen at a faster rate for most years. It may be that a partial switch from cotton to grapes is rational for the farmer even if there is no reduction in canal supplies.

To test this hypothesis, the AGWAT models were run with a larger grape (and smaller cotton) area, for the four villages which already had grapes. In

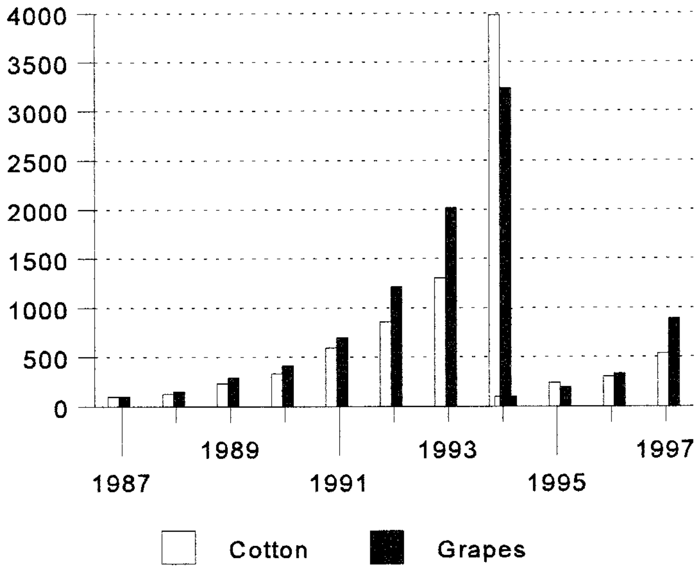

Figure 2. Cotton and grape price indices (State Institute of Statistics, Ankara).

each case, the profitability of a 10% area change from cotton to grapes was calculated. Grapes have a four-year establishment period. During this time the farmer suffers two losses – the expenses associated with setting up the new vines, and the loss of income from the land under them. The farm's profits turn positive again from the 5th year. The rates of return to more grapes, over 25 years, and assuming *no* water supply reductions, are shown in Table 5.

Table 5. Returns to a 10% switch from cotton to grapes, no canal water supply reductions.

Village	Çapaklı	Eldelek	Pazarköy	Çavuşköy
Grape yields	5 T/ha	5.5 T/ha	5 T/ha	4 T/ha
25 year IRR	10%	13%	14%	7%

In general, planting more grapes is a good investment for the farmer. Other than for Çavuşköy, where yields are limited by the groundwater quality and quantity, the real rates of return are 10% or higher. It is perfectly rational for farmers to switch to drought-tolerant crops in response to past or expected water shortages. But, for the Gediz, water shortages are not necessary to explain the observed cropping patterns. It is probable that grapes have become more profitable, especially after the proliferation of wells in the Gediz command,

and with the growing export market. Their drought-resistance could be just an incidental benefit.

Intra-basin reallocation

Earlier in this paper it was shown that, with a 25% drop in aggregate canal supplies, farmers in Salihli remain substantially unaffected. The average Menemen farmer loses between 5% and 20% of his net income, depending on his crop mix. For these scenarios, the implicit assumption was that the DSİ makes proportional cuts throughout the basin, equally borne by all the growers. But is this the optimal allocation strategy for the canal management authorities?

In certain circumstances, the canal managers might have to reallocate water within the basin. In the western USA, for example, impact models with reduced irrigation water indicate that proportional cuts everywhere are sub-optimal. Instead, more of the cuts should come from the regions growing lower-value crops (Sunding et al. 1997). There would be major resistance to such enforced transfers, so this option might not be politically viable in Turkey.[8] Nevertheless, it is worth examining the (simplified) economics of intra-basin reallocation. It may become necessary if the 25% reduction is realised, and then another drought occurs.

In the study area, the relatively unproductive area is the lower delta. Villages such as Maltepe and Tuzculu have poorly drained clay soils, with a high salt content. Such soils are unable to support any crop but cotton. If the canal water became extremely constrained, as in a drought, water might be diverted from Maltepe to upstream Çapaklı. Figure 3 plots the cumulative water use in Maltepe and Çapaklı, against its average productivity. The canal water supply is very tight – only a partial irrigation in July, and in August. In both villages, cotton and maize return 115 TLM/’000 m^3, net of cash costs, but grapes and peaches in Çapaklı give higher returns to water.[9] The difference might be high enough to justify depriving Maltepe of water to protect upstream agriculture, should the canal supply become severely limited.

To gauge the potential for inter-regional allocation, the net returns for the sample farms were computed under moderate surface supply cuts, and again under severe reductions. Table 6 shows the net farm revenues for Çapaklı, at the head of SRB, and Maltepe, at the tail of MLB. The crop patterns in both water supply scenarios are the same. With canal supply reductions of just over 40%, the yields of all the crops, and therefore net farm incomes, fall below those in the 25% reduction case. Even upper and middle Salihli does not have enough well water to make up the difference.

Suppose that the canal water supply falls by 40%. Looking at Table 6, it does not seem rational to divert water away from Maltepe to the upstream villages. To restore Çapaklı to its original level of profitability (2850 TLM

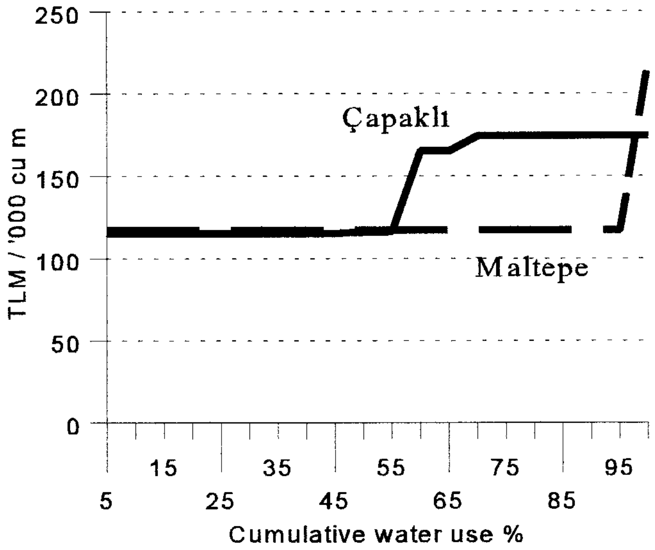

Figure 3. Net returns to water: Çapaklı, Maltepe.

Table 6. Net farm income and water use, moderate and severe water shortfall.

Village	25% reduction Net income; water use	40% reduction Net income; water use
Çapaklı (SRB)	2850 TLM; 20,200 cu m.	2326 TLM; 14,900 cu m.
Maltepe (MLB)	1786 TLM; 14,500 cu m.	1488 TLM; 10,500 cu m.

per farm), Maltepe would have to give up 5300 cu m of water. The financial gain to Çapaklı would be 524 TLM for every 4 ha of land. However, with its remaining 5200 cu m of water, barely half of Maltepe's land could be irrigated. Maltepe would lose more than 700 TLM of net revenue for every 4 ha of land. Therefore there would be a net loss to the basin from the diversion.

The "water shortage" scenarios for the medium term imply that the canal management authorities would do better to encourage productivity-oriented crop changes within each region, rather than water reallocation between regions. In the Gediz, much of the land upstream and downstream is given over to cotton. Hence intra-basin transfers do not make economic sense.

Reducing the water demand

Rather than force an abrupt change in the water supply, the state might consider reducing water demand through manipulating its price policies. What is the probable impact of changing water prices, energy prices, and relative output prices? To assess these impacts, the base case water supplies are retained because price policy is treated as an alternative to, and not in addition to, water supply reductions. Since AGWAT is not an optimising program, the models do not predict the farmer's best response to alternative price regimes. It will, however, compute new returns to water, labour and land, for each price policy. If there are significant changes in these returns, it can be argued that the farmer will have an incentive to alter his crop mix, or his irrigation intensity, or both.

Water prices

Farmers in Turkey receive surface water at highly subsidised prices. Water is charged per crop per unit area, from which the DSİ recovers a small part of its operation and maintenance costs. No payment is necessary for the resource value of water (Çakmak 1997).

Economists generally believe that, all other things being equal, increasing the price of a commodity will lower its demand. Raising canal water prices, it is argued, will lead to more careful applications, adopting efficient irrigation technologies, and switching to higher-value crops (Repetto 1986; Zilberman et al. 1997). But higher water prices will encourage farmers to move to high value crops only if there is a direct relationship between the price charged and the volume received (Perry 1996). When the charges are area-based, water has a marginal cost of zero, and its price will not induce the farmer to save water. This is generally the case in the Gediz Basin. In addition, higher prices can encourage a change in the crop mix only if farmers perceive water costs to be significant in relation to gross revenues. If it is a very small fraction of revenues earned, it will have no allocative impact. This also appears to be the case in the study area.

Figure 4 shows the results of varying the canal water prices in the base case models of Çapaklı and Kesikköy. In Kesikköy (MLB), canal water is priced per hectare, per crop. In Çapaklı (SRB), it is charged per hectare, per irrigation turn. Both these price mechanisms, especially the one in SRB, represent an attempt to combine area-based charges with the volume of water used.

On the X-axis, the price factor of 1 represents the prevailing prices of 1997. The factor of 5 represents a 5-fold increase in these prices. The Y-axis shows the total water costs on the 4 ha farm as a percentage of its gross revenues. For Çapaklı, which uses both canal and well water, the water costs

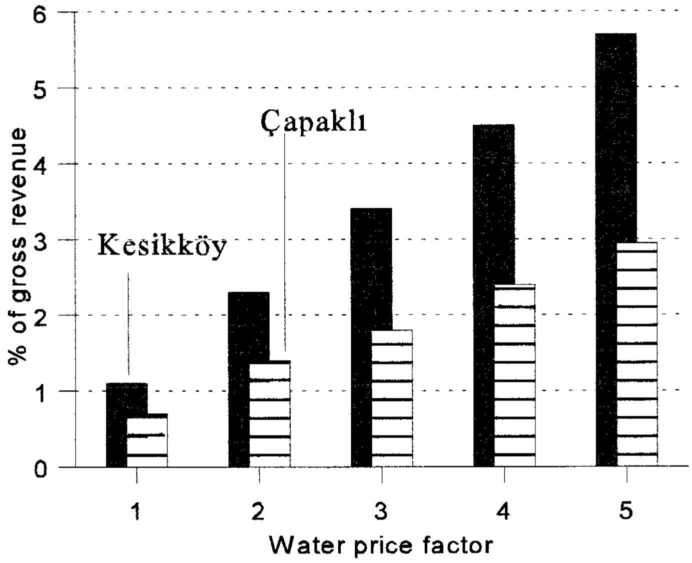

Figure 4. Water costs as percentage of farm gross revenue.

vary from 0.7% to just 2.95% of its gross revenue. It seems unlikely that even a 500% increase in water costs will induce the farmers to change their crops or their cultivation practices. For Kesikköy, representing the Menemen Left Bank, farm water costs go from 1.1% to 5.7% of the gross revenue. That is still a small, though perhaps not insignificant, part of the budget.

A 500% jump in canal water charges is politically highly unlikely. Even if it went into effect, it would generally be too small a component of total revenues to affect water use.

Energy prices

Groundwater, when available to supplement canal water, is also very cheap. This is especially true if the pump is electricity-operated. Many countries, including India, Pakistan and Turkey, subsidise electricity for farmers to encourage them to expand the irrigated area at their own expense (Zilberman et al. 1997). This may be necessary while farmers are still “learning by doing”, but certainly the farmers of the Gediz are well past the learning stage. Pumping costs are the most significant aspect of well costs, once the initial investment has been made. Removing energy subsidies should make farmers pump only as much as is necessary, and only for crops with high returns to water.

Again, this argument is valid only if energy costs are greater than a small fraction of the farm’s gross revenues. In Figure 5, the X-axis shows varying

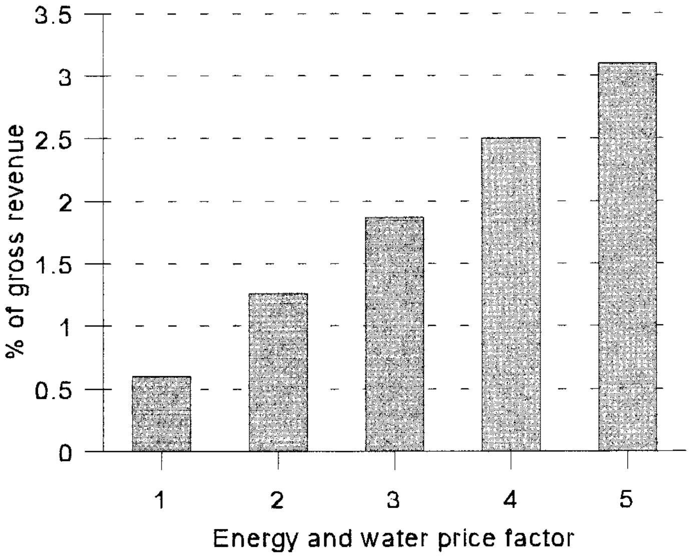

Figure 5. Energy and water costs as percentage of farm gross revenue, Eldelek.

canal water *plus* energy prices for a 4 ha farm in Eldelek. 1 represents 1997 prices and 5 represents a 5-fold increase. The factor of 2 brings electricity charges in line with those for domestic consumers. The Y-axis shows canal water plus pumping costs as a fraction of the farm's gross revenues. Even with surface water and pumping costs 5 times higher than they are today, they together form just 3.1% of the gross revenues in Eldelek. As with surface water, a 500% (real) increase in electricity prices is rather improbable. It can be concluded that, within the feasible range, a farm's water use will likely be insensitive to energy price changes.

Grape and cotton prices

In most of the literature, the focus of studies on price policy and water use has traditionally been on input prices. But in developing countries, as well as in the OECD, output prices are generally quite distorted. In Turkey, the primary means of intervention are deficiency payments (for cotton since 1994) and floor prices (especially for grains and oilseeds). For grapes, fruit and vegetables, especially when processed for the dynamic export market, the prices are free to fluctuate. Grapes and cotton are the two main crops of the Gediz Basin. If the transfer payments for cotton were to be removed, and grape prices continued to rise, then the price ratio would increasingly favour grapes. From Figure 2, this appears to be the trend already.

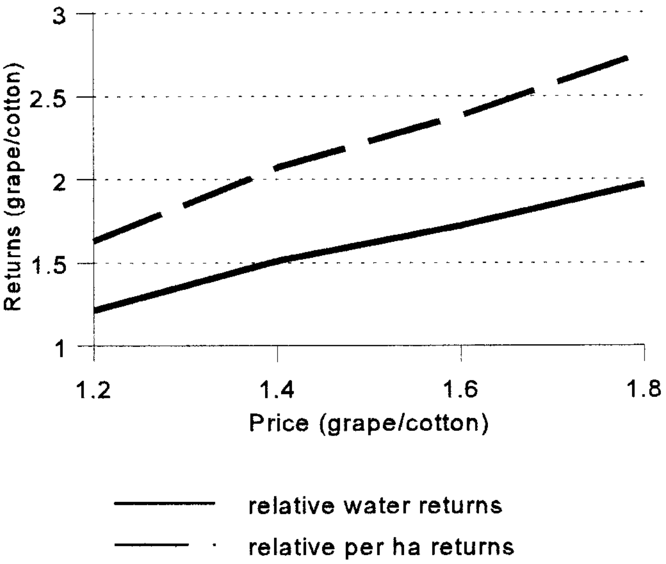

Figure 6. Relative returns and relative prices, grape/cotton; Çapaklı.

On the X-axes of Figures 6 and 7 the relative price of grapes to cotton is plotted, from 1.2 to 1.8. The present ratio (1997 prices) is 1.44. On the Y-axes the relative net returns per hectare, and the relative net returns per '000 m^3 of water, are shown. As the relative returns to grapes increase, the farmer should have a greater incentive to switch out of cotton into grapes. The rate of return to establishing new vines would be even higher than the 10%–14% of the previous analysis. Allowing grape prices to keep pace with international demand, and reducing the level of support for cotton, may not reduce the overall demand for irrigation water. But it could put the water used into higher value crops far more effectively than a change in water prices.

The suggestion that output price policy is a more powerful tool than input price policy may be true beyond the Gediz Basin. From an extensive analysis of Turkish agriculture from 1986–1994, it is clear that farmers benefit from a network of producer subsidies (OECD 1994). Assistance to farmers included market price supports, direct payments and input subsidies. For this period, the net producer subsidies for wheat varied from 20%–52% of the value of production at farm gate prices; for maize, they varied from 26%–46%; for cotton the figures were 15%–47%. Of these subsidies, price supports were 2 to 3 times higher than input cost reductions. If the network of price distortions were to be dismantled – admittedly a politically unattractive prospect – the greater impact would be on output rather than input prices.

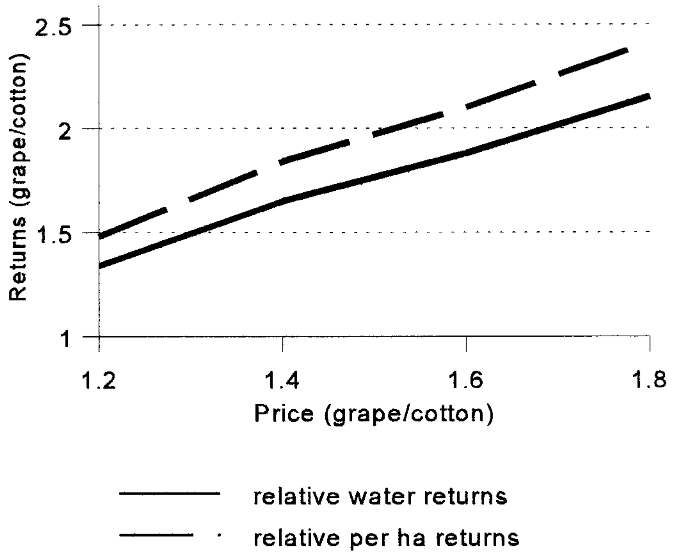

Figure 7. Relative returns and relative prices, grape/cotton; Çavuşköy.

Conclusion

Using parametric variations on six base case farm models, several short- and medium-term “shortage scenarios” for the Gediz Basin were analysed. The scenario comparisons indicate that, should there be a permanent moderate reduction of the surface supply, the DSİ should concentrate the limited water in July and August. The main crops should have their full irrigation requirements met in these two months. Roughly proportional cuts all across the basin are justified with the present crop patterns, and with the predominance of border and furrow irrigation. In the drought of 1989, these were in fact the responses of both the irrigation agency and the farmers.

In the short run, farmers are better off keeping all their land irrigated at lower yield levels, rather than reducing their cropped areas. With a longer time horizon, wells will protect farmers against a moderate shortfall, as long as the water table is kept recharged. But changing over to deep-rooted grapes (or fruit trees) is an economically sound decision even in the absence of anticipated water shortages.

The price policy scenarios indicate that, should water savings be sought from reducing demand rather than supply, energy prices and water prices may not be effective policy instruments. Rather, output price supports should be re-examined. However, within the politically feasible ranges, none of these demand-oriented policies is certain to reduce water use.

For the even longer time horizon, crop patterns, relative prices, market conditions and irrigation technologies will all undergo changes. If more main valley farmers go to drip-irrigated orchards, grapes and vegetables, they will be exposed to much higher yield and price risks. Risk is an aspect which could not be incorporated into these “expected value” models. If more delta farmers want their children to leave agriculture for industry, which they did appear to want, the Gediz Basin could alter dramatically. Both these possibilities are real, but can only be analysed with regional rather than farm-level models.

Looking beyond the Gediz Basin, the input-output data, farm budget structure, and scenario comparison methodology used in this paper are simple to use and apply. The broad range of policy choices considered here establishes a practical framework of analysis for other, potentially water-short basins, within and outside Turkey.

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Notes

1. Other than the various surveys conducted by members of the GDRS/IWMI Project team between 1997 and 1999, the primary source of secondary information for this summary is OECD 1994.
2. All the farmers interviewed were male. Even though some land was held by women, the males of the household were (or claimed they were) the primary decision makers on their family plots. This paper always uses “he” rather than “he or she” to refer to farmers. No stereotyping is intended – the term reflects the public face of all the sampled villages.
3. The irrigation demand was calculated with the widely-used CROPWAT program (Smith 1992), and averaged over 3 consecutive years. The years of, and immediately preceding, this study were without water stress, so it is assumed that the crop net irrigation requirements were being met.
4. These figures are only valid for the prevailing prices and irrigation technologies.
5. Throughout this study, it is assumed that production levels in the basin will not affect prices. For cotton and grapes, the two primary crops, this assumption is entirely justified. The Gediz Basin is only one of many cotton producing regions of Turkey. Grapes (as raisins) are exported, their demand curve is extremely elastic.

6. It is possible that, in the longer run, villages such as Eldelek will have to reduce pumping in order to maintain their water tables.
7. The inflation index calculation was changed in 1994. Figure 2 has 2 base years – 1987 and 1994 – at which both grape and cotton prices are set to 100.
8. One way to counter this resistance is to institute a system of transferable water rights, allowing Irrigation Associations to trade water amongst themselves (Easter & Feder 1997). In Turkey, all water rights are vested with the DSİ at present, and no trades are allowed. The legal infrastructure necessary for water markets does not exist, and the possibility of trades in this paper is not considered.
9. In addition to cotton, Maltepe has a small area of unirrigated wheat. Wheat is profitable in terms of water, but not of land.

References

Bernardo D., Whittlesey N., Saxton K.E. & Bassett, D.L. 1987. An Irrigation Model for Management of Limited Water Supplies. *Western Journal of Agricultural Economics* 12: 164–173.

Çakmak E.H. 1997. Water resources in Turkey: availability, use and management. In: D.D. Parker & Y. Tsur (eds) *Decentralization and Coordination of Water Resource Management* (pp 33–44). Kluwer Academic Publishers, Boston and Dordrecht.

Doorenbos J. & Kassam A.J. 1979. *Yield Response to Water*. FAO Irrigation and Drainage Papers No. 33. Food and Agricultural Organisation of the United Nations, Rome.

Droogers P., Bastiaansen W.G.M., Beyazgül M., Kayam Y., Kite G.W. & Murray-Rust H. 1999. Distributed Agro-hydrological Modelling of an Irrigation System in Western Turkey. *Agricultural Water Management* (forthcoming).

Easter K.W. & Feder G. 1997. Water institutions, incentives and markets. In: D.D. Parker & Y. Tsur (eds) *Decentralization and Coordination of Water Resource Management* (pp 261–282). Kluwer Academic Publishers, Boston and Dordrecht.

Molden D. 1997. *Accounting for Water Use and Productivity*. SWIM Paper 1. International Irrigation Management Institute. Colombo, Sri Lanka.

Murray-Rust H., de Fraiture C., Girgin A. & Droogers P. 1999. Assessing Water Scarcity: An Example from the Gediz Basin, Turkey. Project Report. GDRS/IWMI Collaborative Research Project, Agro-hydrology Research and Training Centre. Menemen, Turkey.

Organisation for Economic Cooperation and Development. 1994. *National Policies and Agricultural Trade. Country study: Turkey*. OECD, Paris.

Perry C.J. 1997. *AGWAT: A User's Guide*. International Water Management Institute. Colombo, Sri Lanka (mimeo).

Perry C.J. 1996. *Alternative Approaches to Cost Sharing for Water Service to Agriculture in Egypt*. Research Report 2. International Irrigation Management Institute. Colombo, Sri Lanka.

Repetto R. 1986. *Skimming the Water: Rent-seeking and the Performance of Public Irrigation Systems*. World Resources Institute, Washington, DC.

Smith M. 1992. *CROPWAT: A Computer Program for Irrigation Planning and Management*. FAO Irrigation and Drainage Papers No. 46. Food and Agricultural Organisation of the United Nations, Rome.

Sunding D., Zilberman D., Macdougal N., Howitt R. & Dinar A. 1997. Modelling the impacts of reducing agricultural water supplies: lessons from California's Bay/Delta problem.

In: D.D. Parker & Y. Tsur (eds) *Decentralization and Coordination of Water Resource Management* (pp 389–410). Kluwer Academic Publishers, Boston and Dordrecht.

Topraksu 1981. Menemen Ovası Temel Toprak Etüdü, Genel Mudurluk. Yayın 236. Raporlar Serisi 24. Topraksu Genel Mudurlüğü, Ankara.

Zilberman D., Dinar A., Macdougal N., Khanna M., Brown C. & Castillo F. 1992. How California Responded to the Drought. Dept. of Agricultural and Resource Economics. University of California at Berkeley (mimeo).

Zilberman D., Chakravorty U. & Shah F. 1997. Efficient management of water in agriculture. In: D.D. Parker & Y. Tsur (eds) *Decentralization and Coordination of Water Resource Management* (pp 221–246). Kluwer Academic Publishers, Boston and Dordrecht.