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A comparative analysis of water price support versus drought compensation scheme

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Abstract

This paper examines the preferred governmental intervention towards crops growing methods in semi-arid regions. These regions are characterized by an average amount of rain which is sufficient to grow the crop but it is also very risky. The farmers' attitude towards risk motivates the government to encourage them to shift to more profitable and riskier crop rotations. The paper analyses two alternatives of which the government can work through: drought compensation scheme (DCS) and water price support (WPS). The semi-arid region in Israel is analyzed and policy conclusions are derived. In particular it is shown that for different sub-regions within the semi-arid region different mechanisms are preferred by the government and the farmers. Sometimes these mechanisms coincide and sometimes they do not. A welfare analyzes compares the different situations. © 1999 Elsevier Science B.V. All rights reserved.

1. Introduction

The major decision-making problems facing a grain farmer in a semi-arid region is the intensity of crop-rotation (that is, what percentage of his land to leave fallowed for next year), when to seed the land and whether to use supplemental irrigation and if yes, how much. Fallowing part of the land (by not growing anything or growing a less harmful crop) allows for water accumulation in the soil and regenerates the fertility of the land serving both as an insurance for the next season as well as a leverage to capture more benefits from a given amount of rain in the next season. However, this should be weighed against the fact that fallowing the land will certainly cause a reduction in yield in the current season.

With respect to the seeding date, an earlier date might 'capture' more rainy days, and therefore, will extend the growing season but in case there will be no rain in the beginning of the season it might be the case that the farmer would have to re-seed again or irrigate. Thus, expanding water that could be used later in the season or for other crops).

This problem is closely related to the problem of supplemental irrigation. Semi-arid regions can segment the market well enough in the winter season. Crops can be grown and be marketed to the major markets even if they are far away because of low enough demand elasticities for these crops. The pro-

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blem arises because these crops are water-intense. The use of supplementary irrigation to ensure grain production comes at the expense of winter crops when irrigation water is scarce.

The general environment surrounding the farmer then, is composed of the following components: grain prices, rainfall and evaporation, government policy and the farmers' attitudes towards risk.

The rainfall and risk attitudes are usually taken to be exogenous to the system. The remaining two components are endogenous since different government policies and pricing policies will result in different outcomes with respect to the farmers' choice of the crop intensity on a given area of land (Freebairn, 1983). There are the three main roles for the government that could influence the final outcome: grain prices, drought compensation scheme (DCS) and water price support (WPS).

In this paper we analyze the case of wheat growing in the semi-arid region of Israel (the Negev) considering the effect of a DCS and WPS. With respect to grain prices the government has few options since Israel is only 50% self sufficient in wheat. To reduce risk, the government announces a promised price at the beginning of the season based on world price outlook as is reflected in the future markets.

The other two mechanisms, namely, DCS and WPS are the most interesting ones, especially in their cost-effectiveness comparison as will be analyzed in this paper.

The economic justification for DCS is the difference between the farmer's and societys desire for wheat production. The difference lies in the attitude towards risk. From the national point of view, the mean profit is the only relevant criterion because of risk spreading considerations (that is from an economic perspective because other reasons such as keeping the land cultivated with something on it could also play a role). However, this is not the case from the farmers' point of view. A risk averse farmer might avoid growing crops at all or choosing to grow less intense rotations because they are not as risky, although less profitable on average.

A DCS will be desirable from an economic perspective if it succeeds in reducing the risk faced by the farmers and in turn will encourage them to shift to more desirable crop rotations (e.g. more profitable). The DCS is actually an insurance program that does not have a premium. However, if the difference in the means of the crop rotations is big enough to compensate for the average annual compensation, then the program will pass a cost-benefit test. This, however, does not come without a price. Problems such as adverse selection and moral hazard can arise because the program takes away the incentive to grow in an efficient way even from the national perspective (Hazel and Valdez, 1986; Hueth and Furtan, 1992; Quiggin et al., 1993).

Supplemental irrigation, on the other hand, reduces the risk as well because it can save the crop from a drought year whenever the rain-water does not suffice. If water prices are subsidized, farmers would start to use their marginal water to irrigate rain-fed crops in addition to vegetables, fruits etc.

Both the farmers and the government face a dilemma in Israel which will be addressed in this paper. Farmers face the dilemma of choosing only one mechanism: either subsidized water or drought compensation, conditional on drought (one cannot enjoy both the mechanisms). The government, on the other hand, has its own dilemma with respect to which tool is a more cost-effective: DCS or subsidized water.

This paper will try to resolve the issue raised here from both perspectives, the farmers' and the government's. It will be shown that it is not necessary that the government's and farmers' choice may or may not coincide.

The method which will be used to verify the farmers choice is the stochastic-dominance criterion. This method was chosen because of its strong general conclusions as well as because of the non-normality of the probability distribution of profits, especially after DCS is introduced (which, like any other insurance program curtails the lower tail of the distribution).

The paper continues as follow: Section 2 gives a short background on the region analyzed. Section 3 summarizes the production possibilities in a simplified way. Section 4 sets up the background for analyzing the two proposed mechanisms: DCS and WPS. In Section 5 we perform a stochastic-dominance analysis on the options the farmers face while in Section 6 we perform a comparative analysis of the two mechanism. Section 7 summarizes the analysis.

2. Background

The semi-arid region of Israel is the northern part of the Negev and is the largest cultivated land area in Israel. Out of a total of 2.7 million dunams (1 dunam = 0.1 ha), about 1.2 million are used for grazing, 1.2 million for non-irrigated field crops (mostly wheat) and 0.3 million for irrigated crops (includes also about 0.15 million dunams of irrigated wheat).

The climate and particularly the rainfall make crop production risky. We divided the region into three main sub-regions with representative villages in each one of them. They are: Dorot (the northern part) with 330 cm annual rainfall, Lahav (the central part) with 306 cm annual rainfall and Gilat (the southern part) with only 218 cm annual rainfall. The variability both among years as well as within a given year is quite high. The probability for drought conditions is about 25–30%. By drought we mean that the revenues from field crops fall short of the production cost. Most of the non-irrigated area is cultivated by communal farms (Kibbutzim and Moshavim). Irrigated crops where introduced especially after the completion of the national carrier, which imports water from the northern part of Israel.

As noted above, the two major mechanisms used by the government are DCS and WPS. With respect to the DCS it covers about 85% of the area and is bordered from north and south by what is known as the 'drought line'[1]. The government compensates the growers up to their break-even level yield whenever the yield falls below that level.

Water, on the other hand, is sold under a given market price. Currently the farmers pay about 10 cents per cubic meter (m^3) while the real price of water supply (that is maintenance and capital cost for the infrastructure) is estimated to be around 30 cents.[2] In addition scarcity rent has to be added which raises the equilibrium price to 40 cents/m^3. The low water paid by the agricultural sector creates a general problem of over demand which is resolved in Israel by (non tradable at the moment) water allotments which in turn creates inefficiencies in the water allocation mechanism (Becker, 1995).

Water is first allocated to crops with relatively low demand elasticity which usually carries a high return for water. Only marginal water remaining are being used to irrigate the grain fields. The question is if one should use them to irrigate summer crops or use them as supplemental irrigation (to rainfall) in the winter for wheat etc. The problem facing the farmer is thus, can he increase his profit from winter field crop production by using these marginal water for wheat but then lose his eligibility for participating in the DCS, or alternatively, avoid paying the 'cheap' price for water (or use them in their opportunity use 10 cents/m^3) but rely on DCS whenever his yield falls below the break even point.

3. Practices of different crop rotations:

At the moment we assume that the only decision variable facing the farmer is the intensity of cropping. That is, how much to leave fallowed each year. We ignore the seeding date problem and for the moment also the supplemental irrigation issue (although we will come back to that question later on).

There are four major crop rotation practices in the region that we concentrated on[3]:

1. A 5 years rotation (20% of the land is left idle each year).
2. A 4 years rotation (25% of the land is left idle each year).
3. A 3 years rotation (33% of the land is left idle each year).
4. A 2 years rotation (50% of the land is left idle each year).

A hydro-biological model (Tzaban, 1981) is used in order to estimate the outcome of these production possibilities. The model estimates daily growth of wheat on the basis of agronomic, climatic, geographical and managerial decisions (seeding date and the choice for supplemental irrigation). Its flow variables are daily precipitation and evaporation while its state

[1]South from the southern drought line there is no economic justification for wheat growing even from the national perspective while north of the northern drought line efficiency dictates shifting to less land intensive crops etc.

[2]There is a difference in transportation cost between the three sub-regions but they are small enough so were ignored in this study.

[3]These methods were noticed to be the most commonly used by the farmers in the region.

Table 1
Weights for different crop rotations

2 year	3 years	4 years	5 years	Rotation weight
0.00	0.33	0.50	0.60	WWS
0.50	0.33	0.25	0.20	WFS
0.50	0.33	0.25	0.20	FS
1.00	1.00	1.00	1.00	Total

WWS = The wheat after wheat share.
WFS = The wheat after fallow share.
FS = The fallow share.

Table 2
Production cost for different rotation shares (in $/dunam)

Gilat (Southern)	Lahav (Central)	Dorot (Northern)	Rotation\ village
18.6	22.0	28.9	W/W
16.6	20.0	27.0	W/F
5.0	6.0	8.5	F

W/W = Production costs for wheat grown on a wheat field.
W/F = Production costs for wheat grown on a fallowed field.
F = Production costs for a fallowed field.

variables are the water storage at eight different soil layers, the root position in the soil, runoff etc. The parameters are the maximum capacity of the given eight soil layers (according to the soil characteristics), as well as the soil moisture at the beginning of the growing season (October). The choice variables where mentioned above: The seeding date if at all and the decision with respect to the supplemental irrigation. At the end of the growing season (end of May) the model predicts the output. For our purposes it is important to note that the initial soil moisture depends on whether the soil was fallowed last year or not.

Translating the 'Wheat model' to the problem analyzed here, there are three positions which the field can be at[4] fallow, wheat after fallow and wheat after wheat. Table 1 describes the different weights of the different positions for the four crop rotations.

Tables 2 and 3 provide production cost data regarding production costs for the different shares in the different sub-regions of the northern Negev (Ministry of Agriculture, 1993). As can be seen from the table, a fallowed unit does require some treatment so the production cost is not entirely zero.

A profile of production costs by crop rotation is possible by combining the data in Tables 1 and 2. It is done by multiplying the production cost in the corresponding field position (at any given sub-region) by the field position share (from Table 1).

To get a predicted weighted output, the Wheat model is run twice for each given year. First we run the model with a fixed seeding date which was found to be the most frequently used: mid-November and without any supplemental irrigation. We then register the predicted output by the end of the season. The second time the model is run in two stages. First we run the previous year's without any seeding date being typed in, so no output is recorded by the end of the season. However, water is accumulated in the different soil layers and are recorded as the relevant initial conditions for next year. The next stage is, then, to run the model with the new initial conditions.

We are in a position now to calculate the predicted weighted output by the following:

$$\mathrm{WO}_j = \sum_{i-1}^{3} \mathrm{pm}_{ij}^{*} S_{ij} \tag{1}$$

Where

WO_{ij} = weighted output (wheat equivalent) for rotation practice i in sub region j.
pm_{ij} = crop rotation practice i for sub region j, and
S_{ij} = share of crop rotation practice i in sub region j.

This can give us the different weights for the different crop rotations and their corresponding output. In order to analyze the profit characteristics in the different sub-regions, meteorological data for 20 years were selected for the three villages described earlier. These data includes daily precipitation and evaporation Israeli (Meteorological Service, 1965–1985). The profit characteristics are given in Table 4.

As can be seen from the table, the four crop rotations practices are profitable from the national perspective, in both the northern sub-region (Dorot) and the central (Lahav). However, the southern sub-region (Gilat) has a negative mean profit. However, it is not clear that risk averse farmers would grow in the most

[4]The entire analysis is done for a 1 dunam unit so there is no importance to the magnitude of the different farms in the region.

Table 3
Profit characteristics before and after compensation

2 year		3 year		4 year		5 year		Statistics Before (B) or after (A)	Rotation village
A	B	A	B	A	B	A	B		
42.7	29.4	58.0	40.0	65.6	45.6	70.9	49.0	Mean	
63.7	−81.1	80.1	102.8	89.1	114	94.2	118.3	SD	Dorot
−37.5	−83	−37.8	−100	−37.9	−111	−38.8	−112	Min.	
36.3	12.2	47.9	13.9	54.0	15.0	58.5	14.2	Mean	
57.2	77.8	70.6	97.8	77.4	107	78.8	112.5	SD	Lahav
−11.1	−61	−7.4	−78	−5.6	−83	−6.0	−85	Min	
22.7	−17.2	33.5	−20.6	39.1	−22.2	44.9	−22.5	Mean	
30.2	52.8	36.9	67.6	40.4	75.6	40.8	78.2	SD	Gilat
1.1	−50	7.0	−63	10.0	−67	15.2	−71	Min.	

All statistics are given in wheat kg, assuming a wheat price of $180 per ton.
Mean = mean annual average profit; (revenues from the wheat model minus production cost from Table 2 transformed into wheat equivalent.)
SD = standard deviation.
Min. = Minimum profit value over 20 years.

profitable pattern if at all, because the variance of the profit brings about a non-negligible probability of ending the season with a loss. Choosing between the different cropping patterns is thus a function of the farmers attitude towards risk.[5]

Table 4
Social and private net benefit with supplemental irrigation (in wheat kg)

Region and rotation	Dorot (Northern)			
	5 years	4 years	3 years	2 years
Social benefit:				
Mean	−5	−9	−1	−14
Private benefit				
Mean	84	74	64	42
SD	110	101	90	69
Min.	−135	−134	−121	−97
Region and rotation	Lahav (Central)			
Social benefit				
Mean	−47	−42	−39	−32
Private benefit				
Mean	45	40	35	24
SD	109	104	93	72
Min.	−118	−111	−98	−73
Region and rotation	Gilat (Southern)			
Social benefit				
Mean	−69	−67	−59	−45
Private benefit				
Mean	20	16	15	11
SD	106	99	86	64
Min.	−127	−124	−91	−57

4. The impact of DCS and water price support

4.1. Drought compensation scheme

The simulated 20 years were analyzed with compensation granted whenever the simulated year did not cover production costs. The results are also presented in Table 4. The compensations are given by a weighted average of the production costs in the different sub-regions of the semi-arid area. This is the reason that the minimum profit (wheat equivalent) does not sum up to zero. In Gilat (the southern sub-region) the minimum profit is above zero because production costs are below the overall average of the entire area. This of course, creates, an adverse selection problem but its significance is probably low due to two reasons: First, the program is totally financed by the government so there is no option to shift to other competing insurance companies. Second,

[5]The fact that the minimum profit observed over 20 years of simulation is connected with the intensity of rotation is only a private case that depends on the price of wheat (In our model assumed to be $180 per ton). It could be, however, that if the price goes down a less intense crop rotation will have both a higher mean as well as lower minimum, a fact that have an impact on the stochastic-dominance analysis carried later on.

probably the cost of operating a totally differentiated program for each sub-region is too high and will fail on a cost-benefit ground in comparison to the current format.

In any event, the simulation model was run as it is currently being operated. The results, however, will have an impact on the results in terms of the choice among the desirable farming methods chosen by the farmers.

It is of interest to note that while in the northern and central sub-regions the most profitable rotation is the five year rotation, both before and after the DCS, in the southern sub-region, it is the less profitable. This fact creates a moral hazard problem as will be seen later on.

4.2. *Supplemental irrigation*

As discussed earlier, the price charged from the farmers is about one third of the real cost of delivering the water to the area (10 cents/m^3 versus 30). However, if a farmer chooses to irrigate his field, he will almost certainly will end up with some profit by the end of the season. This is the reason why the farmer faces either one of two choices: Either irrigate and enjoy the price difference or rely on DCS. After consulting with wheat experts and growers it was decided to run the simulation model with a one time supplemental irrigation of 100 m^3 which is given about 90 days after the beginning of the season (16 December in the 'Wheat model')[6] The results are presented in Table 4. As can be seen from the table, there is a difference between the social and private values of the irrigation. For the social gain, only the mean has to be considered because risk is not a factor from the national perspective (at least at these magnitudes). The individual farmer, however, counts profit as well as risk. This will be used later on in the stochastic-dominance analysis.

However, in calculating the social gain of supplemental irrigation one should consider the real cost of water used while in the private gain, only market price is considered to be a factor[7]. As can be seen from the table, the social gain from irrigation is negative in all three sub-regions. However, private gains are positive for all sub-regions in all rotation methods. On cost-effectiveness grounds it might be concluded that the DCS is more efficient then water price support but things are a little more complicated. This is because one does not know for sure if farmers would shift to the same rotation in both cases, compensation and price support cases. To answer this we need to employ some choice criterion which will simulate the anticipated farmer's reaction under the two different mechanisms.

5. A stochastic-dominance analysis of risky crop rotations

Stochastic-dominance (SD) has become a frequently used technique in Economics and especially agricultural economics since the seminal articles of Hadar and Russel (1969), Hanoch and Levy (1969), Meyer (1977) and Whitmore (1970). The approach is useful in ordering risky strategies especially when it is desired to consider more then just the mean and the variance of the probability distribution (PD). In our case of DCS it is especially useful because insurance programs like the DCS actually curtails the left tail of the PD. This, in turn, effects the normality of the PD which limits the use that can be done with alternative ordering tools such as E-V etc. The approach has been used to analyze a variety of settings including agricultural insurance and other stabilization programs (Kramer and Pope, 1981; Lemieux et al., 1982; King and Oamek, 1983; Zering et al., 1987). Topics such as pest management (Zacharias and Grube, 1984; Greene et al., 1985), Irrigation Scheduling (Bosch and Eidman, 1987) among others were also covered.

SD technique reduces the set of possible strategies to what is called the efficient set. A strategy which is in the efficient set has the characteristic that it is not dominated by any other strategy (either in the set or out of it). A strategy that is out of the set is

[6]Another possibility that was analyzed was to rely on the soil moisture as an indicator for a decision whether to irrigate or not. The results, however, were almost the same as the ones presented here so it was decided to present only the fixed amount per year supplemental irrigation. Detailed results are available from the author upon request.

[7]Water used for supplemental irrigation are calculated by the fraction of the wheat which is grown on the field. That is in the 2 years rotation 50 cm are used etc.

dominated by at least one strategy (either in or out of the efficient set). Dominancy in this respect means that a strategy say F is preferred to another one, say G, by all the individuals in the specified risk interval.

The basis for SD is the expected utility hypothesis which predicts that strategy F will be preferred to G if its expected utility exceeded that of G. Rather then measuring the exact risk preference of the decision maker, it is possible to specify a risk interval by putting bounds on the Pratt–Arrow absolute risk aversion function, $r = -U''(x)/U'(x)$. One can, therefore, reduce the interval and by that reduce the set of efficient strategies but this comes at the expense of accurately knowing that the measured risk interval is indeed the correct one.

In the absence of information regarding the bounds on r, first degree (FSD), second degree (SSD) and third degree (TSD) SD are often used. FSD actually assumes that the risk coefficient, r, can be anywhere between positive and negative infinity. The only assumption underlines FSD, is therefore, the Bernuliann assumption that individuals prefer more to less, that is: $U'(x) > 0$. A more restrictive assumption is that individuals are risk averse. In that case r can be found to be only between zero and positive infinity. In terms of utility it assumes that also $U''(x) < 0$, so utility is increasing and concave. Finally, TSD assumes that $U'''(x) > 0$. Put it differently, it states that as individuals become wealthier, their risk aversion tends to decrease.

The three dominancy criterions could be formalized by the following:

FSD: For the PD's F and G, F FSD G if the following holds:

$$G_1(x) - F_1 \geq 0 \text{ for every } x. \tag{2}$$

Where $G_1(x)$ and $F_1(x)$ are the cumulative probability distribution of G and F, respectively.

SSD: For the PD's F and G, F SSD G if the following holds:

$$H(x) = \int_0^x (G_1(y) - F_1(y))\,\mathrm{d}x \geq 0 \text{ for every } x \tag{3}$$

TSD: For the PD's F and G, F TSD G if the following holds

$$I(x) = \int_0^x \int_0^x (G_1(y) - F_1(y))\,\mathrm{d}x \text{ for every } x. \tag{4}$$

Here FSD requires that cumulative probability distribution (CPD) of F will not lie to the left to the CPD of G. SSD requires that we define another cumulative function, one that measures the area under the original CPD. This function for the PD of F should not lie to the left of that of G. Finally, TSD requires another cumulative function to be determined, one that measures the area under the previous one (used in the SSD). This function for the PD of F should not lie to the left of that of G.

In order to check for SSD which turns out to be the most powerful one (FSD almost does not reduce the efficient set while TSD will not differ much from SSD although it relies on stronger assumptions), it is useful to note the to end points of the risk interval. If $r = 0$, then the individual who is risk neutral, will order the strategies by their means only. On the other hand, if r approaches infinity, it points out on a maxi-min individual who will make his decisions based only on the maximization of the minimal value of the distribution. These are, therefore, the two necessary conditions for SSD (although not sufficient). Identifying two strategies that both conditions hold means that both of them should be included in the efficient set (although one of them could be excluded later on if it is dominated by a third strategy).

5.1. Application

In this research we simplify the method further by taking the discrete version of the PD. Recall that there are 20 observations for each strategy. It is possible, therefore, to create a discrete version of the dominancy criterion by summation (rather by integration) and to check for dominancy.[8] SD rules were constructed for the different crop rotations in the different sub-regions for three scenarios: Before the DCS, after the DCS and with supplemental irrigation (with water price support). The results are given in Table 5 and Figs. 1–3 for the northern, central and southern sub-regions, respectively.

[8] A computer model for the discrete version of the problem is available from the author upon request.

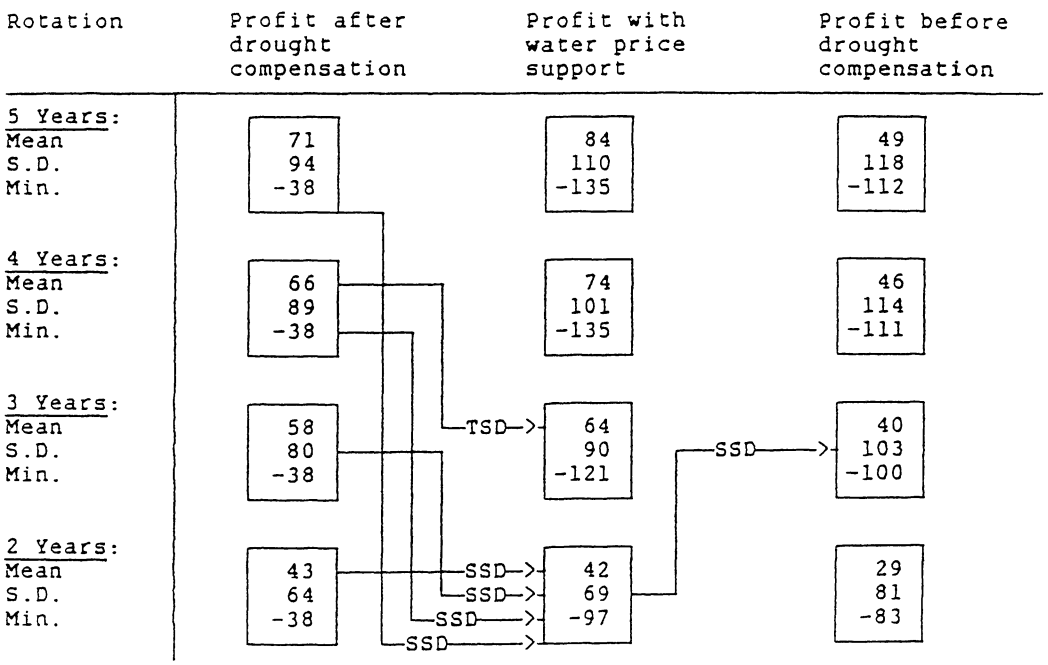

Fig. 1. Dorot-profit without drought compensation, with water price support and with drought compensation: a dominancy analysis.

The results are given only in terms of the strongest dominancy criterion-TSD (which of course includes the SSD and FSD). As seen from Table 5, while in the northern sub-region (Dorot) no crop rotation was excluded from the efficient set, in the central part the 5 years crop rotation was excluded by TSD. In the southern part (Gilat), all the rotations but the 2 years crop rotation were excluded from the efficient set[9].

Table 5
TSD criteria among different rotations

Dorot	Rotation			
Program	5 year	4 year	3 year	2 year
Before DCS	X	X	X	X
After DCS	X	X	X	X
With WPS	X	X	X	X
Lahav	Rotation			
Before DCS		X	X	X
After DCS	X			
With WPS	X	X	X	X
Gilat	Rotation			
Before DCS				X
After DCS	X			
With WPS	X	X	X	X

Note: X represents a rotation which is included in the efficient set

6. A comparative analysis of DCS and water price support

6.1. The social value of the DCS

We start from the DCS only and then introduce the WPS and compare between the two. The DCS should be evaluated on its economic merits of costs and benefits. The benefits are to be measured by the difference in moving to a higher mean crop rotation. The costs of the program are given by the yearly average drought compensation for the crop rotation

[9]Actually because all the rotations have a mean annual profit, they are all dominated by the strategy not to grow, but because growing wheat has other non-economic goals (population dispersion and an original zionistic goal, to make the desert bloom etc.). In order to take these goals into account later on we assumed for consistency that there is some portion of the land which is cultivated and given by the 2 years crop rotation. We come back to this point in the next section.

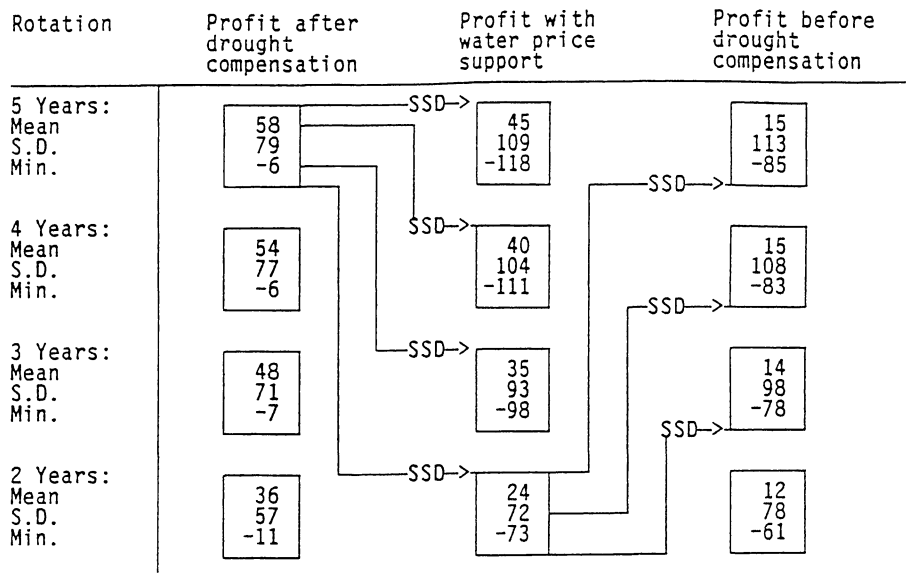

Fig. 2. LAHAV —profit without drought compensation, with water price support and with drought compensation: a dominancy analysis.

that is used after the DCS. This can be written as:

$$SV_{AB} = MEAN_B - MEAN_A - E(COMP_B) \quad (5)$$

Where

SV_{AB} = the social value of moving from crop rotation A–B.

$MEAN_i$ = Mean yearly profit for crop rotation i, and;

$E(COMP_B)$ = Annual average drought compensation for rotation B.

The results for the different crop rotations at the different sub-regions are given in Table 6. We have

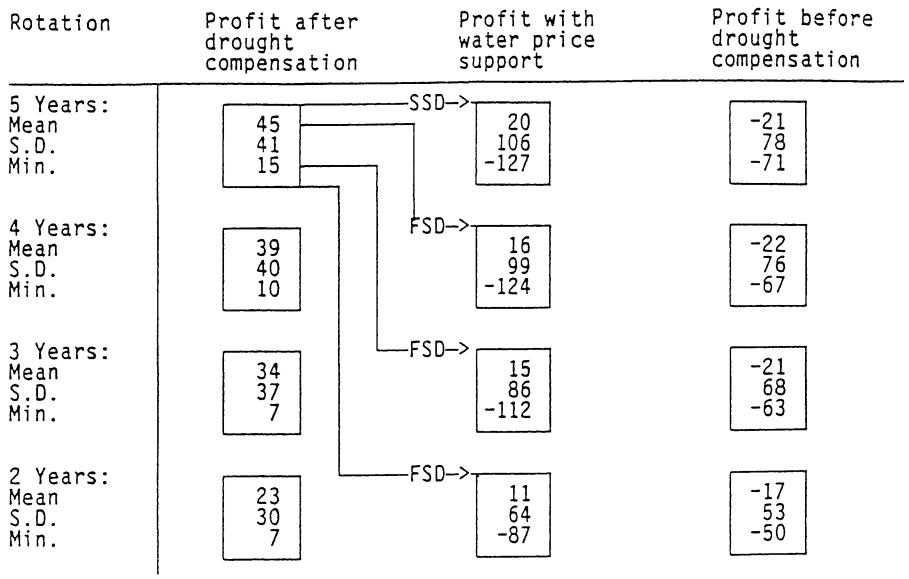

Fig. 3. GILAT-profit without drought comprensation, with water price support and with drought compensation: a dominancy analysis.

Table 6
The Net social benefit of the DCS (in kg/dunam)

Village	Dorot (Northern)					Lahav (Central)			
W/DCS WO/DCS	5 years	4 years	3 years	2 years	No previous growth	5 years	4 years	3 years	2 years
5 years	−22.1	−18.7	−13.1	−2.5	26.9	−41.9	−41.8	−40.7	−39.0
4 years	−24.5	−22.1	−15.5	−4.9	24.5	−39.3	−39.2	−38.1	−36.4
3 years	−26.8	−23.4	−17.8	−6.4	22.2				
2 years	−33.0	−29.6	−24.0	−13.4	16.0				

included only the relevant rotations that remain in the efficiency set after a TSD analysis. The average drought compensation for a given relevant crop rotation can be seen in the diagonal elements in the table. This is because the mean difference vanishes from the last equation and all that remains is the annual average compensation.

The northern sub-region contains all the crop rotations so without knowing more about the risk attitudes of the farmers in the relevant regions, it is impossible to know to which crop rotation will the farmers use after the introduction of the DCS. That being the case, all the possible shifts were calculated according to Eq. (5). In the Central and southern sub-regions we may obtain better results because we know that they will move to either the 4 or 5 year rotation in the central region and to the 5 year rotation in the southern regions. This is why only these possibilities were included in the analysis.

As can be seen from the table, all the shift combinations results in a net social loss except the no growing case in the northern sub-region. That means that other then limited cases in which farmers who did not grow wheat will start to grow in any rotation, all the other shifts do not outweigh the cost of the program.

However, two important points could be elicited from the results. First, it is possible, in theory to operate with a premium free insurance program and still be able to end up with a positive net social gain. Hence, there is a room for optimism for other insurance programs in other regions that do not cover their financial costs but still passes a cost benefit test. Second point is the non-economic social norm of wheat growing in the semi-arid region. The social cost of the DCS could be said to be an approximation of reaching that specific target (see Footnote 9).

Another interesting question is the cost effectiveness of achieving some given level of growing intensity by introducing supplemental irrigation. This is the topic which will be analyzed next.

6.2. *A comparison of DCS versus WPS*

Two interesting questions can analyzed in this context. The first considers the preferred mechanism for both farmers and government. The second considers the choices that the farmers face if the DCS will

Table 7
The net social benefit in a shift from DCS to WPS (in kg/dunam)

Village	Dorot (Northern)				Lahav (Central)				Gilat (Southern)			
With DCS	5 year	4 year	3 year	2 year	5 year	4 year	3 year	2 year	5 year	4 year	3 year	2 year
With WPS												
5 year	−32	−36	−28	−41	−14	−14	−11	−4	18	21	28	38
4 year	−31	−34	−27	−40	−23	−18	−15	−13				
3 year	−27	−30	−23	−36								
2 year	−20	−19	−16	−29								

be eliminated. Here the choice is between rain-fed farming or irrigated farming. In order to analyze these questions we look at Figs. 1–3 and at Table 7. The figures contain dominancy between the two scenarios. The left column versus the center one tries to address the issue of the option the farmers have when they choose between the two mechanisms. The center column versus the right one tries to answer the second question, namely what is the efficient set if the DCS is eliminated. Table 7, on the other hand tries to give the social gain (or loss) of shifting from DCS to supplemental irrigation. This is done by a change in the mean profit due to a shift to crop rotations with subsidized versus crop rotation with out irrigation plus the saved drought compensations. The right column in 15 contains the sum of these two components, which are given in the left and center column. For example, if we consider a move from the 5-year rotation with DCS to the 5-year rotation with WPS, the social gain is −54 (=−5–49) while the saved drought compensations are 22. All together it sums up to −32 as shown in the table. Note that in the case the farmers grow wheat without WPS, then Table 6 should be the basis for the analysis.

Considering first at the northern sub-region, it is clear from Table 7 that from the national perspective it is more efficient to compensate rather to subsidize water. There is a social loss in moving to the WPS in all cases as can be clearly be seen from the right column of Table 7. But looking, at Fig. 1, we notice that when both mechanisms are offered together, the 3 and 2 year rotation with WPS are eliminated from the efficient set. So, there is a possibility that farmers will grow five and four year crop rotations with WPS even though cost-effectiveness shows the DCS as the preferable mechanism. If, on the other hand the government eliminates the DCS, then as can be seen from Table 7, only the three year rotation without supplemental irrigation is being excluded from the efficiency set. So, in the northern sub-region, farmers and government prefers different mechanisms.

In the central sub-region (Lahav), it is also better to compensate rather to support the water price. However, in contrast to the northern sub-region, here the five year rotation with DCS dominates all four rotations with supplemental irrigation. That means that here the government and the farmers prefer the same mechanism which was obviously not the case in the northern sub-region(!). If the DCS is terminated, then all except the two year rotation are being excluded from the efficient set. Hence, if farmers will not choose a 2 year rain-fed crop rotation, then the social loss will increase by eliminating the DCS.

Turning last to the southern sub-region (Gilat), it better to support water prices rather to compensate in case of a drought. The reason is that the value both of marginal productivity of water and of drought compensations increases from the north to the south. Thus, the desirability of the DCS decreases towards the south. Farmers, however, know this and as can be seen from Fig. 3 the 5 year rotation dominates all four rotations with WPS (and, of course, al the other three rotations in the left column of Fig. 3 as was discussed earlier). If, on the other hand, the DCS will be eliminated, farmers in the southern sub-region will choose between rotations with WPS and not growing at all. This means a net gain relative to the DCS situation.

The major conclusion that could be inferred from this analysis is that the government should try to eliminate as much as possible the use of supplemental irrigation in the northern sub-region (use only the DCS option), while encouraging the use of supplemental irrigation in the southern sub region (thus eliminating the use of DCS in that sub-region). This could be done by gradual changes in the water price support and the DCS according to the region. In the central sub-region government's and farmers' goals coincide, so there is no need to create an incentive to move from one mechanism to the other (although refinement in the DCS could be considered such as the maximum amount of reduction in the compensation that will still cause the farmers to behave as they currently do).

7. Summary

In this paper the Stochastic-Dominance approach was used in order to analyze the impact of the two major mechanisms that the government employs in order to encourage farmers to shift to more profitable (but also riskier) crop rotations in the semi-arid region in Israel. To that end, several crop rotations were defined and ranked according to stochastic efficiency criterions. It was argued that stochastic-dominance is the best tool because it can handle also non-normal

distributions e.g., like crop distributions which are affected by insurance programs.

On a cost-benefit ground, the current conditions points out that the DCS fails, except for the case were it influence farmers to grow wheat in any rotation, while not growing at all without the DCS. However, as could be seen in the paper, it is only a private case and it could be that the DCS will pass a cost-benefit test. That is, insurance programs that do not charge a full premium (or do not charge premium at all as is in our case), still might have an economic value. An alternative that was not analyzed in this paper is to reduce the payments under the DCS and see then under what minimum payment the farmers would still move to the more riskier rotations.

Government also influence farmer' decisions by supporting the water price. This was shown to be clearly inefficient from the national perspective. However, there are other non-economic goals to government intervention in this region that were mentioned in the paper. In that case it was suggested to conduct a comparative analysis of the two mechanisms in order to see which mechanism will cost less in achieving a given target (in our case-crop intensity). The results point out that as much as one go south to a less rainy area, the desirability of DCS declines and that of the water price support increases (the opposite occurs towards the north). From the stand point of the farmers, the situation may appear different. While in the Northern region it is not clear what would they prefer whiteout having better notion of their risk preferences, in the south there is a clear conflict between farmers and the government because farmers would definitely prefer drought compensations rather use subsidized water. In the central region, it was found out that government and farmers goals coincide. Both would prefer compensation on water price support.

The results might suggest some policy changes that have some Pareto improvement potential. These changes might take the form of charging higher prices for water in the northern area while reducing the compensations paid in case of a drought in the southern area.

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