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Utility Maximizing Investment in Well Capacity for Conjunctive Use of Ground and Surface Water at the Farm Level in Southern Iran

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ABSTRACT

Conjunctive use of ground and surface water can increase reliability of the water supply by providing independent sources. In this study, corrected utility-efficient programming that allows for more than one seasonal irrigation depth for each crop was used to determine the amount of utility maximizing investment in the well capacity for conjunctive use. Results showed that optimum investment at the 15% discount rate for the small, medium and large representative farms with a low degree of risk aversion is 150341, 531592.7 and 1084648 thousand Rials, respectively, which decreases as aversion to risk increases.

Keywords: Conjunctive use, Ground and surface water, Risk-efficient investment.

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INTRODUCTION

The innately random nature of surface water gives groundwater an important role as a contingent supply for times when the flows of surface water are below average (Burt, 1976). The value of the role of groundwater in stabilizing supplies through improving reliability and reducing the impact of drought can be even greater than its role in adding to total quantity (Tusr, 1990; Tusr and Graham-Tomasi, 1991). Therefore, conjunctive use of ground and surface water can increase the reliability of the water supply by providing independent sources (Lettenmaire and Burges, 1979; Fisher *et al.*, 1995).

Farmers' available irrigation supply in most districts of Fars Province, southern Iran, includes their share of irrigation water from rivers as well as installed capacity for pumping groundwater. At the beginning of the growing season, an estimate of the stream flow is made for the entire growing period. On the basis of that estimate and the installed capacity to pump groundwater, farmers make their cropping pattern decisions in an effort to maximize their utility for the year. If their only supply is surface water and the surface water is less than what was planned for, they must decide which crop to irrigate with how much water in order to continue to maximize their utility for that season. As the capacity of pumping ground water increases, a shortage of surface water can be compensated for by its equivalent groundwater withdrawal. The problem becomes one of how large should the pumping capacity in the system be? In other words, to put it in economic terms, what is the utility maximizing investment in well capacity? Due to the recent prolonged drought in southern Iran, this has become an important question.

The international literature is filled with the studies on conjunctive water management (Gangwar and Toorn, 1987; Bredehoeft and Young, 1983; Gorelick, 1988; lingen, 1988; O'Mara, 1988; Brewer and

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Sharma, 2000; Datta and Dayal, 2000; Raju and Brewer, 2000; Sakthivadivel and Chawala, 2002; Chaudnry and Shah, 2003; Waqar *et al.*, 2003; Kumar and Singh, 2003; Hafi, 2003; Qureshi *et al.*, Tturral and Mashi, 2004; Schmidt *et al.*, Hanson and Maddock, 2004). Studies on the conjunctive use of surface and groundwater are usually based on the assumption that farmers try to maximize profit under perfect competition. Considering the existence of imperfect information (risk and uncertainty) and the socioeconomic context within which farmers operate, this assumption of profit maximization is unsatisfactory (Lipton, 1968; Dillon and Anderson, 1971; Upton, 1979). Consequently, more realistic behavioral assumptions should be made in modeling farmers' decision-making. This paper contributes to the literature on incorporation of risk in conjunctive use by developing the utility-efficient programming that allows for more than one seasonal irrigation depth for each crop.

Specific objectives of this paper were to:

1) Identify and value the costs and benefits that will arise with the conjunctive use of ground and surface water and compare them with the situation as it would be without conjunctive use under different climate conditions.

2) Determine the optimum amount of ground water for conjunctive use at the representative farms.

3) Assess utility-maximizing investment for each representative farm.

MATERIALS AND METHODS

Farmers' decision making problems in different fields, such as conjunctive use of ground and surface water, may be regarded as one of constrained utility optimization under risk and uncertainty. Various methods for handling utility optimization under risk in agriculture are reported in the literature (e.g. Anderson *et al.*, 1977; Hazel and Norton, 1986; Hardaker *et al.*, 1991; Hardaker *et al.*, 2004). However, when there are many decision makers, such as some group of farmers for whom advice is being suggested, it would be desirable to develop an efficient set of farm plans. This can be achieved using utility-efficient programming (UE) (Hardaker *et al.*, 2004). Utility efficient programming is a land allocation model that optimally allocates the available area among different crops when water is not limited or when water is limited but the objective is to maximize the net benefit per hectare or when water is limited but crops are to be irrigated with a certain irrigation strategy that may be optimum with non-irrigation considerations. These models, consider only one level of water application depth and based on this depth, the areas to be irrigated under different crops are optimized. In water limiting conditions, this type of land allocation may not be optimum because the last few increments of water applied to a crop, which result only in small yield increase, may generate better yields if applied to additional land. Therefore, it is necessary to consider various irrigation strategies for each crop. In order to overcome this problem, different irrigation strategies for each crop were simulated to determine water requirement and crop yield associated with each irrigation strategy. The basic structure of various levels of seasonal irrigation depth for the studied crops is shown in Appendix 1. As shown in this table, the name of each activity has two parts. The first part is the name of the crop and the second indicates the level of seasonal irrigation depth. The information provided by the simulation model was then used in the utility-efficient programming model to determine the optimal cropping pattern, the optimal irrigation strategy for each crop and the amount of utility maximizing investment in the well capacity. The utility-efficient programming model in GAMS language can be summarized as follows:

The objective function of the model is the expected utility (E (U)) that can be evaluated as:

$$E\ (U) = e = sum[t,\ U\ (t) * P\ U\ (t)] \qquad (1$$

in which:

U (t) is the utility at time t and P U (t) is the probability of receiving U (t). The objective function must be maximized subject to the following constraints:

1. Total cropped land area cannot exceed the total land area available for planting at each month (land (m)):

*sum (C, L (c,m) * X(c)= L= Land (m)* (2

in which:

L (c, m) is the land requirement for activity c at month m.

X(c) is the land area allocated to activity c.

2. Summation of water requirement for each crop at each month can not exceed total water supply from groundwater (GW (m)) and surface water (SW (m)) at each month, that is:

*Sum[c, W(c, m) * X(c)]= L= (SW(m) + gw(m) * eff_a * eff_c)* (3

where, W(c, m) is the water requirement for activity c at month m. eff_a and eff_c are application and conveyance efficiencies respectively.

3. The aggregate of labor requirement for each crop can not exceed total available labor at each month (Labor (m)), thus:

*sum [c, lab (c, m) * X(c)]= L = labor (m)*(4

in which:

lab (c, m) is the labor requirement for crop c at month m.

4. Summation of cash flow requirement for each crop at each month cannot exceed the total cash flow available at each month (cash (m)). Therefore, assuming cash (c, m) is the cash requirement for crop c at month m, we can write:

*sum [c, cash (c, m) * X(c)] = L= cash (m)*(5

5. Total profit for each state Z (t) can be calculated as:

*sum [c , b (t, c) * X(c)] – TFC = e = Z(t)* (6

where, b (t, c) is the gross marginal for activity c at state t, and TFC is total fixed cost.

6. Total Utility for each state U (t) can be calculated as:

$U(t)= e= 1- exp [-\{(1-a) * r_{min} + a r_{max}\} * Z(t)]$(7

In this negative exponential function, a varies between zero and 1, which provides coefficient of absolute risk aversion between r_{min} when a is zero and r_{max} when a is 1. The above UE model of the representative farms will be solved by using the GAMS/MINOS 5 and can be expected to generate a set of solutions that are statistically efficient for all decision makers whose coefficient of absolute risk aversion is in the relevant range.

The data used in this study were collocated from various sources. Applying a two-stage cluster sampling, farm level data were obtained from a sample of 145 farmers in the Kavar district that is a suitably representative example for the plains of Fars Province that lies in southern Iran. At the first stage, a cluster of 12 villages in Kavar were selected. In the second stage, 145 farmers were chosen in these villages, by using a systematic random sampling method. Sample farmers were then interviewed to collect the input-output data and the amount of available resources and other information needed. Data on farmers' risk attitudes and their subjective beliefs regarding crop yields and prices were obtained from a sub-sample of 42 farmers drawn from the main sample.

While the means and variances of yield, price and gross margin for each crop were estimated subjectively, it proved impossible to obtain a subjective estimate of covariance directly from the farmers. Therefore, time series data of yields, prices and gross margins covering 26 years (1974-1999) were gathered from the Regional Branch of Management and Planning Organization to address this problem, as is explained later.

RESULTS AND DISCUSSION

Construction of a model for each sample farm is time consuming, costly and inefficient. Therefore, cluster analysis was applied to the farm data such as land in crops, land-to-labor, land-to-water, land-to-capital ratio and net income per hectare to find homogenous groups in the sample farms. This analysis improves the selection of representative farm and reduces aggregation bias (Hazell and Norton, 1986). Based on this analysis, three clusters were recognized in terms of farm sizes. The farms were clustered as 6.5 ha and smaller (small farms), larger than 6.5

ha and smaller than 15 ha (medium farms), and 15 ha and larger (large farms). The median farms of each group were chosen as representative farms after ranking them on the basis of their land area. The representative degree of the median was tested by comparing the returns per ha of each selected farm to the average of corresponding size class.

In this study, a triangular distribution method was used to measure subjective probabilities about prices, yields, maximum yields, gross margins and maximum gross margins. Historical data on yields, prices and gross margins (GMs) were corrected for inflation and the trend by fitting a trend regression to the (inflation corrected) series for each individual activity, finding the deviations of each observation from the trend, then applying these deviations to the corresponding current-year trend values of GMs in order to construct the de-trended series. To generate estimates of covariance, time series of GM for each crop were reconstructed by expressing the historical trend and inflation-corrected GMs for each crop in terms of standard normal deviates about the mean, then substituting the standard deviation derived from the subjective GM distributions. The subjectively adjusted time-series data were then used as alternative states of nature in the programming models for the representative farms.

The negative exponential form of the utility function [u (x)=1-exp (-r_ax)] was fitted to each set of data obtained by ELECE (Equally Likely Certainty Equivalent) method to yield estimates of the coefficients of absolute risk aversion, r_a, for each farmer. The r_a values ranged from 0.00000065 to 0.000050 for the small farms, from 0.00000022 to 0.000045 for the medium farms and from 0.00000015 to 0.000031, for large farms. The results are similar to that reported by Zuhair *et al.* (1992); Torkamani and Hardaker (1996); Bar-Shira *et al.*, Just and Zilberman (1997). Hence, all the sampled farmers were recognized to be risk averse.

The results of UE model of representative small, medium and large farms with conjunctive use and under normal climatic condition are given in Table 1. As shown in this table, increasing aversion to risk results firstly in allocating less land to more risky activities such as onion production, with concomitant increases in wheat and sugar beet acreages. Secondly, in decreasing water use for all crops, especially for more risky crops. In other words, farmers selected crops with low levels of seasonal irrigation depth as aversion to risk increases. Therefore, deficit irrigation strategies can be selected by farmers even though water is not limited. The findings for land allocation are similar to those reported by Torkamani and Hardaker (1996) and, for water allocation, are similar to those reported by Harris and Mapp (1986) and Pandey (1990). The results of the expected profit maximization model are presented in the last column of these tables. The difference between the total expected profit of this plan and utility-efficient plans at relevant range of risk aversion indicates the impacts of risk aversion on farmers' profits. One would expect there to be a trade-off between expected profit and the variance of that profit. In other words, an increase in expected profit is required to offset increased variance. Conversely, in order to reduce the variance, a farmer is willing to reduce expected profit.

In order to identify and evaluate the costs and benefits that will arise with the conjunctive use of groundwater and surface water and to compare them with the situation as it would be without conjunctive use, UE models were solved without conjunctive use and under different climate conditions. The results for the representative medium farm are presented in Tables 2 to 4. As shown, under water limiting conditions, i.e. without conjunctive usage, total operated land decreased especially for a second corn crop and more water-intensive crops such as onions. In other words, conjunctive use permits farmers to produce a second corn crop and increase their total operated land. For example, at the 0.0000003 risk aversion level, total operated land with conjunctive use is 16 ha but, without conjunctive use, it de creases to 8.87, 7.92 and 7.29 ha under wet,

Table 1. The results of UE model for the representative medium farm with conjunctive use under normal climate conditions.

Activity levels (ha)	Utility-efficient plans at relevant range of risk aversion									EPMP[a]
	0.0000005	0.0000006	0.0000007	0.0000008	0.0000009	0.0000015	0.000002	0.000003	0.000004	
Wheat1	6.304	6.318	7	6.050	7	8	8.092	0	0	4.765
Wheat2	0	0	0	0	0	0	0	0	0	2.485
Wheat8	0	0	0	0	0	0	0	8.822	8.539	0
Corn1	0	0	0	0	0	0	0	0	0	6.006
Corn2	0	0	0	0	0	0	0	0	0	0.994
Corn3	7	7	7	6.06	7	6.063	3.287	3.288	2.112	0
Onion1	1.750	1.750	0	0	0	0	0	0	0	0
Onion5	0	0	1.750	1.750	1.750	1.001	0.898	0.165	0.461	0
Sugar beet1	0.250	0	0	0	0	0	0	0	0	0
Sugar beet4	0	0	0	0	0.250	0	0	0	0	0
Alfalfa	0	0.250	0.250	1.200	0	0	0	0	0	0
Expected profit (1000 Rials)	133866.5	133195.2	120692.3	121783.2	120523.3	101213.1	70746.7	45111.5	39231.2	142767.7

[a] Expected profit maximization plan

Table 2. The results of UE model for the representative medium farm without conjunctive use under normal climate conditions.

Activity levels (ha)	Utility-efficient plans at relevant range of risk aversion							EPMP[a]
	0.0000005	0.0000010	0.000001	0.000002	0.000003	0.0000035	0.000004	
Wheat4	0	0	0	0	0	0.724	4.200	0
Wheat5	0	0	4.200	4.200	4.381	3.783	0	0
Wheat7	4.200	4.200	0	0	0	0	0	4.200
Barely1	0	0	0.005	0	0	0	0	0
Corn3	2.474	2.426	2.411	2.693	2.706	2.528	2.192	2.426
Corn5	0	0.311	0	0	0	0	0	0.311
Onion6	0.294	0	0.637	0	0	0	0	0
Onion1	0.926	0.926	0.693	0	0	0	0	0.926
Onion3	0.030	0.030	0	0	0	0	0	0
Onion4	0	0	0	0	0	0.336	0	0
Onion5	0	0	0	0	0.662	0	0.110	0.030
Expected profit (1000 Rials)	57239.8	57252.3	54225.3	52484.3	43305.7	44135.1	31106.4	57252.3

[a] Expected profit maximization plan

normal and dry climate conditions respectively. The acreage of corn at this level of risk aversion with conjunctive use is 7 ha which, without conjunctive use, decreases to 3.56, 2.76 and 3.02 ha under wet, normal and dry climate conditions, respectively. As indicated in Tables 2 to 4 when water is a limiting factor, the selection of deficit irrigation strategies such as wheat4, wheat5, wheat6 and wheat7 instead of wheat1; corn5 and corn6 instead of corn3 and onion5 instead of onion1 is a general rule for all crops.

Determination of optimum amount of groundwater for conjunctive use was another important objective of this study. The optimum amount of groundwater for conjunctive use at the representative small, medium and large farms level under normal climate conditions ranged between 13,794.9 and 36,262.9, 29,741.6 and 169,782.1, and 198,505.9 and 390,608.6 m^3 $year^{-1}$, respectively. Corresponding figures for a dry year ranged between 29,050.2 and 46,904.2, 64,005 and 201,557.1, and 305,981.6 and 242,500.8 m^3 $year^{-1}$, respectively. The optimum demand for groundwater in order to conjunct with surface flows at the representative small, medium and large farms under wet climate conditions ranged from 0 to 11,932.8, 16,978.9 to 142,751.9 and 168,072.3 to 359,611.3 m^3 $year^{-1}$, respectively.

There is usually little assurance that predicted outcomes will coincide with actual ones. This lack of certainty about the future makes economic decision making one of the most challenging tasks faced by farmers. If probability distributions are used to describe economic elements, the expected value of cost or profit can provide a reasonable basis for comparing alternatives. The expected profit or cost of a proposal reflects the long-term outcome that would be realized if the investment were repeated a large number of times with its probability unchanged. Because most farms are long-lived, the expected value as a basis for comparison seems to be a sensible method for evaluating investment alternatives under risk. The long-term objective of such farms may include the maximization of expected profits or the minimization of expected costs. To include the effect of the time value of money where risk is involved, all that is required is to state expected profits or costs as expected present worth, or expected annual equivalents. Expected annual equivalent of profit, E (A), is defined as the summation of different annual equivalent profit levels multiplied by their respective probability of occurrences. Based on the historical data for the last 50 years, the probability of occurrence for normal, dry and wet climate conditions in Kavar district are 0.42, 0.34 and 0.24. Thus, the expected annual equivalent profit of conjunctive use for the medium representative farm, whose coefficient of absolute risk aversion is 0.000008, is computed as follows:

27108.23+ 30103.84 + 12503.16 =69715.23

Expected annual equivalent profit of conjunctive use for medium representative farms at relevant range of risk aversion were computed and are shown in the last column of Table 5.

The incremental investment in well capacity is considered to be desirable if

$$-I+E(A)(P/A,\ i,\ n)>=0 \Rightarrow E(A)(P/A,\ i, n)> I \quad (8$$

where:

I = Investment in the well capacity

i = Minimum attractive rate of return

n = Economic life of well capacity.

E(A) (P/A, i, n)= Pw (i)= is the present worth, P, of expected annual equivalent profit of conjunctive use at minimum attractive rate of return, i, and for the whole economic life of well capacity. $(P/A, i, n) = \left[\frac{(1+i)^n - 1}{(1+i)^n i}\right]$ is known as the equal-payment–series present–worth factor. This factor may be used to find the present worth, P, of a series of equal periodic payment.

Thus, utility maximizing investment, in well capacity, must be less than the present worth of the series of expected annual equivalent profit of conjunctive use. In fact, the present worth, P, of this series is the break-even point of investment in the well capacity. The values of the break-even point of investment in well capacity at n=35 andi

Table 3. The results of UE model for the representative medium farm without conjunctive use under wet climate conditions.

Activity levels (ha)	Utility-efficient plans at relevant range of risk aversion								EPMP[a]
	0.0000005	0.0000007	0.0000008	0.0000010	0.000001	0.000002	0.000003	0.000004	
Wheat1	0	0	0	0	0	0	0.757	0	0
Wheat5	0	0	4.200	4.200	4.321	0	0	5.306	0
Wheat6	0	0	0	0	0	1.517	0.009	0	0
Wheat7	4.200	4.200	0	0	0	0	0	0	4.200
Wheat8	0	0	0	0	0	2.683	5.616	0	0
Barley1	0.136	0	0	0	0	0.607	0	0	0
Barley2	0	0.302	0.492	0	0	0	0	0	0
Barley4	0	0	0.110	0.541	0	1.767	0	0	0
Corn3	3.111	3.108	3.011	3.030	3.226	3.228	3.503	2.725	3.104
Corn5	0	0	0.095	0	0	0	0	0	0.06
Corn6	0.067	0.079	0.386	0	0	0	0	0	0
Onion1	1.348	1.339	1.065	1.059	1.094	1.089	0	0	1.355
Onion5	0	0	0	0	0	0	0.278	0.150	0
Expected profit (1000 Rials)	72957.6	72888.7	69686.7	69238.9	61083.1	60246.6	47555.9	39093.7	72981.9

[a] Expected profit Maximization plan

Table 4- The results of UE mode for the representative medium farm without conjunctive under dry climate condition

Activity levels (ha)	Utility-efficient plans at relevant range of risk aversion						EPMP[a]
	0.0000005	0.0000006	0.0000008	0.0000009	0.000003	0.000004	
Wheat4	1.225	1.225	1.225	1.225	1.225	1.341	1.225
Wheat5	1.759	1.759	1.759	1.759	1.759	2.108	1.759
Wheat6	1.290	1.290	1.290	1.290	1.290	0.751	1.290
Corn3	1.521	1.521	1.524	1.732	2.302	2.302	1.521
Corn5	1.364	1.364	1.304	1.288	0	0	1.364
Expected profit (1000 Rials)	3324.5	33242.5	33242.5	33187.5	29626.7	29626.7	33242.5

[a] Expected profit Maximization plan

Table 5. Expected profit with and without conjunctive use for the medium representative farm (1000 Rials).

Range of risk aversion	Expected profit with conjunctive use	Expected profit without conjunctive use			Differences between with and without			Expected annual equivalent profit
		Normal conditions	Dry conditions	Wet conditions	Normal conditions	Dry conditions	Wet conditions	
0.0000005	133866.5	57239.8	33242.5	72957.3	76626.7	100624	60909.2	81013.58
0.0000006	133195.2	57239.8	33242.5	72957.3	75955.4	99952.7	60237.9	80342.28
0.0000007	120962.3	57239.8	33242.5	72888.7	63452.5	87449.8	47803.6	67855.85
0.0000008	121783.2	57239.8	33242.5	69686.7	64543.4	88540.7	52096.5	69715.23
0.0000009	120523.3	57239.8	33187.5	69686.7	63283.5	87335.8	50836.6	68474.03
0.00000010	120523.3	57252.3	33187.5	69238.9	63271	87335.8	5083604	68468.73
0.00000015	101213.1	52484.3	33187.5	61083.1	48728.8	68025.6	40130	53226
0.00000020	70746.7	52484.3	33187.5	60246.6	18262.4	37559.2	10500.1	22960.3
0.0000030	45111.5	43305.7	29626.7	47555.9	1805.8	15484.8	-2444.4	5436.6
0.0000035	39601.7	34135.1	29626.7	39093.7	5466.6	9975	508	5809.4
0.0000040	39231.7	31106.4	29626.7	39093.7	8125.3	9605	138	6711.45
EPMP	14276.7	57252.3	33242.5	72981.6	85515.4	109525.2	69786.1	89903.70

Table 6. Break-even point of utility maximizing investment in well capacity.

Risk aversion	Utility maximizing investment in well capacity (10% discount rate)			Utility maximizing investment in well capacity (15% discount rate)			Utility maximizing investment in well capacity (20% discount rate)		
	Small farm	Medium farm	Large farm	Small farm	Medium farm	Large farm	Small farm	Medium farm	Large farm
Low	219136.5	774837	1580957	15034.1	531592.7	1084648	113417.4	401028.5	818248.1
Moderate	113046	660326.1	1274319	77557.51	453030.2	874272.1	58505.65	341761.7	659542.9
High	44712.50	64726.53	1184262	30675.92	44406.95	812486.8	23141.6	33500.18	612932.3

equal to 10%, 15% and 20% (the weighted average of formal and informal interest rate in homogenous groups) for small, medium and large representative farms at a low, moderate and high level of risk aversion were computed and are given in Table 6. As shown in this table, utility maximizing investment in well capacity at the 15% discount rate for small, medium and large representative farms with a low degree of risk aversion are 15,034.1, 531,592.7 and 1,084,648 thousand Rials (approximately $=8800 Rials in 2005), respectively, which decrease as aversion to risk increases.

CONCLUSION

Determination of investment in the capacity for conjunctive use at farm level is an important issue due to the recent prolonged drought experienced in southern Iran. The international literature is filled with studies on conjunctive water management. Risk as a critical element that is ignored in the most of these efforts. Because yield and price cannot be forecasted with certainty, land and water are allocated under risk and uncertainty. Thus, it is vital to incorporate risk in the land and water allocation models. This paper contributes to the literature on incorporation of risk in conjunctive use by developing the utility-efficient programming that allows for more than one seasonal irrigation depth for each crop. In order to identify and evaluate the costs and benefits that arise with conjunctive use of ground and surface water and to compare them with the situation as it would be without conjunctive use, UE models for the representative farms were solved with and without conjunctive use under different climatic conditions. Results indicated that conjunctive use permits farmers to produce a second crop and increase their total operated land and select more intensive irrigation strategies. In this study, probability distributions were used to describe economic elements. Based on the historical data for the last 50 years, the probability of occurrence for normal, dry and wet climate conditions in southern Iran are 0.42, 0.34 and 0.24, respectively. The expected annual equivalent of profit of conjunctive use was therefore defined as the summation of different annual equivalent profit levels multiplied by their respective probability of occurrences. The present value of the series of expected annual equivalent profit of conjunctive use at different degrees of risk aversion for representative farms was the break even point of incremental investment in the well capacity in these farms. The results indicated that utility maximizing investments in well capacity at 15% discount rate for small, medium and large representative farms with low degree of risk aversion are 150,341, 531,592.7 and 1,084,648 thousand Rails, respectively, which decrease as aversion to risk increases.

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Appendix 1. The basic structure of various levels of seasonal irrigation depth for crops.

Crops	Net water requirement (m^3 per ha)									y_a/y_p*
	Nov and Dec	Jan, Feb Mar	Apr	May	June	July	Aug	Sep	Oct	Ratio
Wheat 1	146	570	958	1762	940	0	0	0	0	0.988
Wheat 2	146	570	1106	1249	940	0	0	0	0	0.890
Wheat 3	146	570	1106	1021	940	0	0	0	0	0.822
Wheat 4	78	570	729	1021	940	0	0	0	0	0.764
Wheat 5	146	570	946	776	669	0	0	0	0	0.726
Wheat 6	78	394	769	722	864	0	0	0	0	0.664
Wheat 7	78	394	730	725	526	0	0	0	0	0.516
Wheat 8	78	217	806	725	526	0	0	0	0	0.468
Barley 1	39	491	1178	1539	120	0	0	0	0	0.960
Barley 2	39	562	1108	739	120	0	0	0	0	0.738
Barley 3	24.5	326	790	739	120	0	0	0	0	0.663
Barley 4	24.5	54.3	411	790	60	0	0	0	0	0.468
Corn 1	74.7	0	0	0	0	947	1499	1923	1512	0.980
Corn 2	944	0	0	0	0	611	1499	1479	1512	0.901
Corn 3	592	0	0	0	0	544.2	850	1450	652	0.850
Corn 4	592	0	0	0	0	544.2	850	1450	622	0.800
Corn 5	780	0	0	0	0	456	1499	830	1512	0.730
Corn 6	482	0	0	0	0	456	1449	642	1402	0.628
Corn 7	482	0	0	0	0	413.2	1040	642	1402	0.531
Corn 8	535	0	0	0	0	947	956	885	896	0.486
Onion 1	0	154	813	1611	2297	2222	2158	1837	492	0.991
Onion 2	0	153	813	626	2297	2222	2158	1837	492	0.897
Onion 3	0	154	813	1611	2297	2222	860	1837	492	0.867
Onion 4	0	154	813	1611	2297	2222	0	1730	492	0.775
Onion 5	0	130	601	0	750	2222	2156	554	492	0.730
Onion 6	0	154	813	626	1550	2222	1382	554	492	0.639
Onion 7	0	154	813	377	1550	2222	0	554	492	0.505
Onion 8	0	134	360	377	1550	2222	0	554	492	0.393
Sugar beet1	0	204	766	1571	2348	2400	2393	1982	670	0.961
Sugar beet2	0	204	766	1571	2348	2400	1599	1890	0	0.904
Sugar beet3	0	204	436	1571	2348	800	1282	1890	0	0.708
Sugar beet4	0	204	136	649	2348	800	1282	1890	0	0.503
Sugar beet5	0	204	136	559	1600	800	1282	1890	0	0.362
Alfalfa	669	446	870	1471	2210	2204	2168	2046	1400	1

میزان سرمایه‌گذاری حداکثرکننده مطلوبیت در زمینه حفر چاه به منظور استفاده تلفیقی آب سطحی و زیرزمینی در سطح مزرعه

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چکیده

استفاده تلفیقی از آب سطحی و زیرزمینی با تأمین منابع مستقل، اتکاپذیری آب را افزایش می‌دهد. در این مطالعه با به‌کارگیری روش برنامه‌ریزی مطلوبیت -کارای اصلاح شده که امکان لحاظ کردن بیش از یک عمق آبیاری برای هر محصول در آن وجود دارد، میزان سرمایه‌گذاری حداکثرکننده مطلوبیت در زمینه ظرفیت‌سازی بهره‌برداری از آبهای زیرزمینی به منظور استفاده تلفیقی تعیین شد. نتایج نشان می‌دهد که سرمایه‌گذاری بهینه در نرخ تنزیل ۱۵ درصد برای مزارع نماینده با اندازه کوچک، متوسط و بزرگ در سطح ریسک گریزی کم به‌ترتیب ۱۵۰۳۴۱، ۵۳۱۵۹۲/۷ و ۱۰۸٤٦٤۸ هزار ریال است که با افزایش ریسک‌گریزی کاهش پیدا می‌کند.

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