ECONOMICS OF SOIL AND WATER CONSERVATION

IN IRRIGATED AND DRY LANDS AGRICULTURE

By

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To the Faculty of Washington State University:

The members of the committee appointed to examine the thesis of ANDREY ZAIKIN find it satisfactory and recommend that it be accepted.

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ECONOMICS OF SOIL AND WATER CONSERVATION

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Abstract

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This thesis is divided into two papers focusing on economics of soil and water conservation in irrigated and drylands agriculture. Part 1, "Economic Comparison of the Undercutter and Conventional Tillage Systems for Winter Wheat-Summer Fallow in Adams County, WA, 2006," compares the economic competitiveness of the undercutter and conventional fallow tillage systems on a case study farm located near Ritzville, WA. Part 2, "Economic water and land resource allocation under the state order requirements on the example of Namangan region, Uzbekistan," describes an developing an analytical model and analyzing water and land allocation for growing cotton and wheat under the state order requirements in eastern part of Uzbekistan.

Results in Part 1 show that undercutter tillage has net return advantages over conventional tillage due to lower costs and receiving conservation payments. Conservation

payments had an effect on the profitability of the undercutter tillage WW/SF systems for the Eastern Washington farms. Adopting a soil conserving undercutter fallow tillage will also diminish wind erosion and protect health and the environment in downwind areas.

Results in Part 2 show that farmers can expect to earn higher incomes when they grow more cotton even without any government determination of what to grow. The results of the model shows that adopting improved irrigation methods improving field irrigation efficiency would allow farmers to not only minimize the effect of water shortage but also to achieve higher yield and consequently higher net farm returns for both of these crops.

TABLE OF CONTENTS

LIST OF TABLES

PART 2. ECONOMIC WATER AND LAND RESOURCE ALLOCATION UNDER THE STATE ORDER REQUIREMENTS ON THE EXAMPLE OF NAMANGAN REGION, UZBEKISTAN

Appendix Tables

LIST OF FIGURES

PART 1

ECONOMICS COMPARISON OF THE UNDERCUTTER AND CONVENTIONAL TILLAGE SYSTEMS FOR WINTER WHEAT-SUMMER FALLOW IN ADAMS COUNTY, WA, 2006

Summary

Wind erosion and blowing dust are major problems for the dominant conventional tillage winter wheat-summer fallow cropping system in eastern Washington. Wind erosion reduces soil productivity and damages air quality. Reduced tillage summer fallow, which can reduce wind erosion markedly, is used by relatively few farmers in the region. This bulletin compares economic results for the undercutter and conventional fallow tillage systems on a case study farm located near Ritzville, WA with an average of 11.5 inches of annual precipitation. The average wheat yield on the case study farm is 47 bu/ac. This study shows that undercutter tillage is more profitable on the case study farm due to slightly lower costs and to conservation incentive payments.

Introduction

Winter wheat-summer fallow (WW-SF) is a traditional dryland cropping system in the semiarid US Pacific Northwest. This region averages 15 inches or less annual precipitation. The system offers economic advantages such as higher average profitability, reduced financial and production risk and more even seasonal demand on labor and machinery.

Fallow stores additional water in the soil profile reducing the possibility of crop failure from drought and higher yields. Weeds are controlled with economical mechanical tillage. On the other side, traditional fallow reduces crop residue and surface roughness that increase the potential for wind erosion.

Blowing dust from summer fallow land damages air quality in the region's urban areas. Airborne particulates damage human health, raises household and industrial cleaning costs, and can cause traffic accidents. In addition to air pollution, wind erosion contributes to loss of topsoil and long-run soil productivity. Scientists and farmers have sought soil conserving WW-SF systems such as minimum tillage, delayed minimum tillage, and chemical (no-till) fallow.

Conventional and conservation fallow tillage differ in operations, timing and production costs. Conventional tillage includes up to eight operations during fallow, especially use of the rodweeder implement, not including planting. Chem-fallow and conservation tillage require only zero to five operations. These systems increase surface residue and roughness generating more protective cover against wind erosion. The undercutter system uses a V-shaped blade for primary tillage which cuts the roots of weeds without inverting the soil. It also severs the capillary route of evaporating water from the seed zone. However, questions remain about the profitability and risk of some forms of conservation tillage WW-SF in the region. This publication compares the economic performance of conventional tillage with reduced undercutter tillage fallow on a case study farm near Ritzville in Adams County, Washington.

The area is characterized by cool winters, hot dry summers and frequent winds. Annual precipitation averages 11.5 inches.

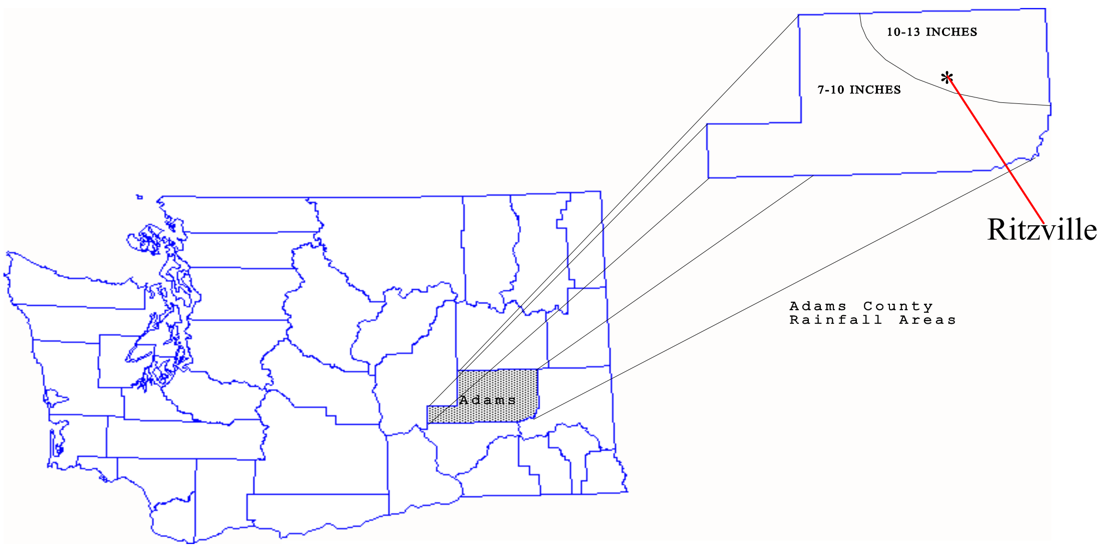

Figure 1. Study site location within Washington state

Economic cost of production budgets are prepared for each WW-SF system. Economic budgets produce higher costs than cash budgets because they include all opportunity costs or foregone returns. They include foregone returns on all owned resources such as land rent on land that is owned, interest on owner's machinery equity, and a wage for the owner-operator's labor. Economic budgets also include all cash production expenses.

The budgets represent costs and returns on a particular farm which used both the undercutter and conventional tillage systems for WW-SF. As stated in the Note at the beginning of this bulletin, conditions and practices on other farms may cause costs and profitability to differ from those reported here.

Background

Summer fallow became a traditional practice in semiarid eastern Washington when farming began in the late 19th century. Intensive summer fallow tillage controls weeds during the fallow year and creates a four-to-six inch deep dust mulch to reduce soil water evaporation and conserve water in the future seed-zone.

Papendick (2004) indicates that tillage-intensive fallow is an unsustainable long-term farming practice because of depletion of soil organic matter. Walker and Young (1986) show the cost of lost soil productivity by long run soil erosion. Wind erosion also imposes social costs by harming human health and imposing other negative effects in downwind areas.

Washington State University (WSU) scientists have sought solutions for reducing wind erosion from irrigated and dryland croplands. Schillinger et al. (2001a), in a study in Lind, WA (9 in ppt/yr), showed that undercutter minimum tillage and undercutter delayed minimum tillage performed equally well as conventional fallow tillage in terms of grain yield and weed and disease control. Averaged over five years, the soil water content in the seed zone as well as total storage was not affected by tillage treatment (Schillinger, 2001a). This conservation wheat-fallow system also provides marked reduction in wind erosion.

However, conservation fallow tillage is not widely used in eastern Washington (Janosky et al., 2002). Based on the last reliable estimate for 1998, 88% of fallow small grain acreage in Adams County was conventionally tilled (CTIC). Researchers have cited several reasons why farmers do not adopt conservation fallow tillage: inadequate seed-zone moisture for early planting, difficulties in controlling grass weeds, plugging of grain drills due to excessive straw, and concern about the financial risk of converting to conservation farming systems (Janosky, et al., 2002; Juergens et al., 2001, Ogg, 1993).

This bulletin is intended to help alleviate some of economic concerns about conservation fallow tillage and to help farmers learn more about the undercutter tillage system. Adoption of this system could promote the environmental and economic sustainability of farming in lower rainfall zones of the Pacific Northwest.

Source of Information

The information for this publication was obtained through repeated contacts with an Adams County wheat producer who recently has used conventional and undercutter fallow tillage. The wheat producer provided detailed information on machinery, field operations, inputs used, overhead costs and yields. The 2006 price information was obtained from local agricultural supply businesses and from a recent study in the same area (Nail, 2005).

Budget Assumptions

The following cost accounting assumptions were followed:

1. The representative farm for undercutter and conventional practices include 5,000 acres each with 2,500 acres for summer fallow and 2,500 acres for winter wheat. Two budgets (summer fallow and winter wheat) were developed for each tillage practice. Table 1 describes the timing of field operations and inputs represented in the WW-SF systems from the case study form.
2. Winter wheat yields of 47 bu/ac were used for both the undercutter and conventional systems based on the 8-year average yield (1998-2005) of primarily conventional system yields on the case study farm. Equivalent yields for the two systems were assumed based on statistically equivalent yields from these two systems in a five-year experiment at Lind, WA (Schillinger, 2001a).
3. The utilized soft white wheat prices of $3.32/bu is based on five-year (2001-2005) average at the Lind, WA grain elevator. (www.unionelevator.com/charts.htm). Government commodity “direct payments” are $6.75/ac.
4. The undercutter fallow tillage system qualifies for conservation incentive payments of $20.40/ac.
5. Machinery types and costs, and input types and rates are from the case study farm.
6. The off-road price of diesel for January 2006 is $1.94/gl. (http://tonto.eia.doe.gov/oog/info/gdu/dieselpump.html). Price of labor is $12.00 per hour. The interest rate is 6.5%. Other input prices are listed at the Appendix Table A15.

The budgets represent the case study farm. Where such factors as farm size, machinery type and use, cultural practices, and yields differ from those assumed in this publication, substantially different enterprise costs and returns may result. Furthermore, these budgets contains only production costs and do not consider storage, handling, transportation, and interest costs associated with marketing the crop.

Discussion of Budget Information

Detailed budgets of production costs were developed for each tillage system using Washington State University's Farm Enterprise Budget Simulator (FEBS). Each tillage practice consists of two budgets: summer fallow and winter wheat after fallow. The undercutter and conventional systems have different generalized field operations and timing (Table 1). The two cultivations lead to less surface roughness and residue in the conventional fallow tillage system.

Schedule of Operation and Costs per Acre for Summer Fallow – Winter Wheat: Appendix Tables.

Detailed budget information for the fallow and winter wheat budgets by tillage system are presented in the Appendix. The "Schedule of Operations …" tables outline the schedule of field operations by calendar month, the type of machinery used, and the hours

Table 1. General Field Operations and Inputs for Summer Fallow and Winter Wheat after Summer Fallow by Tillage System, Ritzville, WA, 2005

Date	Undercutter	Conventional
Summer Fallow		
Aug	Undercut at 2" (every five years)	Undercut at 2" (every five years)
Nov	Rip (every three years)	Rip (every three years)
Mar	Spray Herbicide:14 oz Roundup/acre, 8 oz Ammonia Sulfate/acre and 0.05 gl surfactant/acre (every year)	Spray Herbicide:14 oz Roundup/acre, 8 oz Ammonia Sulfate/acre and 0.05 gl surfactant/acre (every year)
Mar		First Cultivation (every year)
Apr	Spray 10 oz Roundup/acre (every five years)	Second Cultivation (every year)
Apr	Undercut at 4" & Fertilize: 50lb N/acre and 5lb S/acre (Using Undercutter) (every year)	
May	First Rod Weed (every year)	
Jun	Second Rod Weed (every year)	Fertilize: 50lb N/acre and 5lb S/acre (every year)
Jun		First Rod Weed (every year)
Jul	Third Rod Weed (every two years)	Second Rod Weed (every two years)
Winter Wheat		
Late Aug	Plant 40lb/ac registered seed and fertilize at 10lb of P_2O_5/ac	Plant 40lb/ac registered seed and fertilize at 10lb of P_2O_5/ac
Mar	Spray Herbicide: 10 oz 2,4-D/acre, 0.9 oz Olympus/ac (every two years)	Spray Herbicide: 10 oz 2,4-D/acre, 0.9 oz Olympus/ac (every two years)
Jul	Harvest & Transport Grain	Harvest & Transport Grain

used per acre and total production costs for summer fallow and winter wheat. The production costs are divided into two categories. The first category is fixed costs that include costs related to fixed machinery ownership, land costs, and management. The second category is known as variable costs that are associated with operating machinery, hiring labor, and purchasing services and materials. Fixed and variable costs sum to total costs.

Machinery fixed costs include depreciation, interest on investment, property taxes, insurance, and housing costs. For the overall operation, fixed costs do not vary with the acres of crop produced, given the ownership of a specific machinery complement. The per-hour fixed costs are determined by dividing the total annual fixed costs by the annual hours of machinery use for the farm. Machinery fixed costs for a specific field operation are determined by multiplying the machinery hours per acre times the per-hour fixed costs (Appendix Table A9). In Appendix Tables A3 and A4, the previous year's summer fallow costs, plus interest, are included as part of the fixed cost of raising winter wheat. These are costs that must be covered by wheat sale if the enterprise is to remain profitable over the long run.

Variable costs vary directly with the crop grown and the number of acres produced. Variable costs include machinery repair, fertilizer, pesticides, fuel, custom hire services, crop insurance, overheard, and interest on operating capital. Machine operating labor, including that provided by the owner-operator, is also included as a variable cost.

Land fixed costs include property taxes and net land rent. Net rent is based on rental agreement typical for the area minus expenditures typically covered by the landlord. The "typical" lease agreement for wheat is a one-third landlord crop share with the landlord paying land taxes, one-third of the fertilizer cost, one-third of the crop insurance and one-third of the chemical cost for weed control. The tenant covers all other production expenses.

As an example, the net land rent per 2 acres for summer fallow-winter wheat with undercutter tillage is calculated as follows:

$52.01	(one-third gross receipts from production)
- $10.66	(2 years land tax; summer fallow and winter wheat)
- $0.67	(one-third chemical costs for weed control; summer fallow and winter wheat)
- $8.14	(one-third fertilizer)
- $1.67	(one-third crop insurance costs)
$30.87	Net rent per 2 acres

While the owner-operator does not actually experience a land rental cost, the net rent cost represents the minimum return the owner-operator needs to justify growing the crop on his/her land. This return represents the income the owner-operator foregoes by producing this crop rather than renting to a tenant who produces the crop. Land cost is an opportunity cost for an owner-operator rather then an out-of-pocket expense. Of course, rent is cash cost for tenants. Appreciation in land value are not considered as past of the returns in this wheat enterprise.

Itemized Costs per Acre: Appendix Tables.

Appendix Tables A1 and A3 itemize the costs for summer fallow and winter wheat, respectively. Most of the items are self-explanatory or have been previously explained. One entry, “Interest on Machinery,” warrants additional explanation. Fixed machinery interest costs are calculated on the average annual investment in the machine:

$$\text{Interest Cost} = (6.5\%)\ \frac{\text{(Purchase Cost + Salvage Value)}}{2}$$

Interest cost represents either an opportunity cost (return foregone by investing in the given machine rather than in an alternative investment) or interest paid on money borrowed to finance machine purchase, or both. Interest costs for one acre of summer fallow or winter wheat is determine by multiplying the respective machine and/or tractor hours per acre time the per hour interest costs (Appendix Table A9). Prices used for fuel, fertilizer, chemicals, seed, and other inputs are listed in Appendix Table A15.

Machinery Complement and Hourly Machinery Costs.

Table A9 identifies the equipment and building complement from the case study farm used to derive machinery costs. Typically, most pieces of machinery on Adams County farms of the representative size are purchased both new and used depending on what is available and desired at the time of needed machinery replacement. This table includes the type of machines used on the case study farm, their current “average” replacement value (new or used), years of use before trade-in, salvage value at trade-in, and annual repair costs. The data in Appendix Table A9 are used to estimate the per-hour fixed and variable machinery costs.

Profitability and Sensitivity Results

Table 2 compares net returns over total costs for the conventional versus undercutter fallow tillage systems with and without conservation payments. Total costs represent both cash and opportunity cost for land and machinery, owner labor and other inputs. Two net returns measures are reported in Table 2, without and with conservation incentive payments. Only the undercutter method qualifies for conservation payments. For both systems, government commodity "direct payments" for wheat growers are added to market returns to compute gross return. No countercyclical or loan deficiency payments under the 2002 Farm Bill had been received by soft white wheat growers at the study site.

Table 2. Comparing gross returns and net returns over total costs for conventional versus undercutter tillage for a farm case study, winter wheat-summer fallow with and without conservation payments, Ritzville, WA.

	Unit[a]	**Undercutter Method**	**Conventional Method**[b]
Gross Returns:			
Wheat Yield	bu/ac	47	47
Wheat Price	$/bu	3.32	3.32
Market Return (Yield x Price)	$/2ac	156.04	156.04
Direct Government Payments	$/2ac	13.50	13.50
Gross Return	$/2ac	169.54	169.54
Total Costs	$/2ac	204.43	209.74
Net Return (without Conservation Payments)	$/2ac	-34.89	-40.20
Conservation Payments			
EQIP	$/2ac	40.80	NA[b]
Net Return (with Conservation Payments)	$/2ac	5.91	NA[b]

[a]Values/2ac include both the fallow and winter wheat year. If desired, values per rotational acre (0.5 ac of WW and 0.5 ac of SF) could be obtained by dividing by two.

[b]Undercutter method qualifies for conservation payment, but conventional method does not.

Table 2 shows that undercutter tillage has a net return advantage of $5.31/2 ac over conventional tillage. The profit advantage is due to $5.31/2 ac lower costs for the undercutter because both systems are assumed to enjoy the same yields, wheat prices, and commodity payments. The undercutter system's profit is markedly strengthened by conservation payments which raises the profitability advantage to $46.11/2 ac, due to the conservation payment of $40.80/2 ac. However, neither of the two tillage system was able to generate sufficient market returns at low $3.32/bu wheat prices to cover total costs without conservation payments. Undercutter and conventional tillage systems lose $34.89 and $40.20 respectively per 2 acres (Table 2). Negative market net returns over total cost, not uncommon in grain production, indicate that not all the farm's resources are earning market returns. However, the undercutter tillage system generates a positive profit of $5.91/2 ac by receiving a conservation payment of $40.80/2 ac. The results show that undercutter tillage has potential as an effective best management practice relative to conventional tillage in WW-SF production in eastern Washington.

Table 3 presents (breakeven) prices and yields required for gross returns to cover total costs for the conventional and undercutter systems. The break-even analysis indicates that with an equal average grain yield for the undercutter and conventional tillage systems of 47bu/ac, prices of $4.06/bu for undercutter tillage and $4.18/bu for conventional tillage system are required to cover total costs. The calculations include a direct payment of $13.50/2 ac and total costs of $204.43 for the undercutter and $209.74 for conventional tillage systems per 2 acres. With a wheat price of $3.32/bu and without conservations payments, breakeven yields 53.4bu/ac for undercutter and 55.0bu/ac for conventional tillage systems plus direct payments are necessary to cover total costs (Table 3).

Table 3. Prices and yields required for gross returns to cover total costs (break-even values) for conventional versus undercutter method of winter wheat-summer fallow production with and without conservation payments, Ritzville, WA farm case study.

	Unit[a]	Undercutter Method	Conventional Method[b]
Without Conservation Payments			
Price	$/bu	3.78	3.89
Yield	bu/ac	53.4	55.0
With Conservation Payments			
Price	$/bu	3.19	NA[b]
Yield	bu/ac	45.2	NA[b]

[a]Values/2ac include both the fallow and winter wheat year.

[b]The undercutter method qualifies for conservation payment, but conventional method does not.

The break-even analysis shows that the conservation payment provides a substantial benefit to the undercutter system. A break-even price of $3.19/bu is required to cover total costs for this system with the payment. This is $0.80/bu lower than for conventional tillage which does not qualifies for the conservation payment. Breakeven yield for the undercutter drops to 45.2bu/ac with the payment. Gaining a conservation payment reduces the financial and production risk of farmers willing to try this new tillage system.

Table 4 compares results of recent WW-SF economic studies in Adams County, WA, including this study. The table compares fixed, variable, total costs, wheat yield and market net returns. No conservation or direct payments are included. Wheat price is held constant at $3.50/bu for all studies which causes results to differ slightly from Table 2. At net returns of -$40/2 ac to -$56/2 ac, the results of this study reported here project slightly lower profitability than the other studies listed in Table 4.

Table 4. Comparison of fixed, variable, total costs, wheat yields, and market net returns for selected winter wheat-summer fallow studies, Adams County, WA.

Source	Fixed costs ($/2 ac)	Variable costs ($/2 ac)	Total costs ($2/ac)	Yields (bu/ac)	Prices ($/bu)	Market Net Return ($/2 ac)
Undercutter. This study (2006)	137.79	66.64	204.43	47.0	3.50	-39.93
Conventional. This study (2006)	142.85	66.89	209.74	47.0	3.50	-45.24
Min-till (2005) [a]	67.55	94.83	162.38	30.5	3.50	-55.63
Nail et al., conventional (2004)	86.83	61.65	148.48	45.9	3.50	12.17
Hinman & Esser, system 1[b], 7"-10" PPT/yr (1999)	61.39	61.39	122.78	35.0	3.50	-0.28
Hinman & Esser, system 2[c], 7"-10" PPT/yr (1999)	59.04	71.42	130.46	35.0	3.50	-7.96
Hinman & Esser, system 1[b], 10"-13" PPT/yr (1999)	81.91	77.51	159.42	52.0	3.50	22.58
Hinman & Esser, system 2[c], 10"-13" PPT/yr (1999)	81.10	88.52	169.62	52.0	3.50	12.38

[a]This study, based on a different case study farm in Adams County, is reported in the Appendix (Appendix Tables A10-A14).
[b]System 1 primarily uses a tillage operation with lower rate of fertilizer.
[C]System 2 uses an aerial application of Roundup-RT and higher rates of fertilizer.

These differences, in part, are attributable to recent inflation in costs, especially for fuel and fertilizer. Data of this study, based on detailed records of a case study farm, may also have captured a more complete set of costs. Other differences, of course, are likely due to different farm machinery complements and practices, plus differences in crop yields due to varying soil and climate.

Variability in market net returns reflects different production costs and gross returns. Wheat prices and diesel prices, for example, have both fluctuated widely in recent years in respond to market forces. To illustrate the possible impacts of these price changes, Tables 5 and 6 display the effect of wheat price and diesel price variation on net returns (with eligible payments) for the undercutter and conventional tillage systems.

Table 5. Net returns over total costs ($/2 acres) for undercutter winter wheat-summer fallow tillage with conservation and direct payments at varying wheat prices and off-road diesel prices.

Wheat Price ($/bu)	Change (Δ) in Diesel Price					
	%Δ	**-50%**	**-25%**	**0%**	**+25%**	**+50%**
	$/gl	**0.97**	**1.46**	**1.94**	**2.43**	**2.92**
2.00		-28.99	-32.22	-35.45	-38.69	-41.92
2.50		-13.33	-16.56	-19.79	-23.03	-26.26
3.00		2.34	-0.89	-4.12	-7.36	-10.59
3.50		18.01	14.78	11.55	8.31	5.08
4.00		33.67	30.44	27.21	23.97	20.74
4.50		49.34	46.11	42.88	39.64	36.41
5.00		65.01	61.78	58.55	55.31	52.08

As shown by the shaded area of Table 5, the results for undercutter tillage indicate that wheat prices of $3.50/bu or more earn profits at all diesel prices when conservation payments are received. Losses of -$41.92/2 ac to profits of $65.01/2 ac bracket the most pessimistic and optimistic price assumption in Table 5.

Table 6 presents a similar sensitivity analysis for the conventional tillage WW-SF system, only this system is not eligible for conservation payments. Except for the two lowest diesel prices, the farmer fails to cover total costs whenever wheat price is $4.50 or less.

Table 6. Net returns over total costs ($/2 acres) with direct payments for the conventional tillage system at varying wheat prices and off-road diesel prices.

Wheat Price ($/bu)	Change (Δ) in Diesel Price					
	%Δ	-50%	-25%	0%	+25%	+50%
	$/gl	0.97	1.46	1.94	2.43	2.92
2.00		-74.58	-78.07	-81.56	-85.05	-88.54
2.50		-58.91	-62.40	-65.89	-69.38	-72.87
3.00		-43.25	-46.74	-50.23	-53.72	-57.21
3.50		-27.58	-31.07	-34.56	-38.05	-41.54
4.00		-11.91	-15.40	-18.89	-22.38	-25.87
4.50		3.75	0.26	-3.23	-6.72	-10.21
5.00		19.42	15.93	12.44	8.95	5.46

Conclusions

Fragile soils, drought and high winds combine to promote dust storms and soil erosion on tilled summer fallow in eastern Washington. This study compared the profitability of undercutter (conservation tillage) and conventional tillage summer fallow on a case study farm in Adams County, WA. Net returns over total costs, including direct and conservation payments, were $46.11 per 2 ac higher for the undercutter than the conventional tillage system. However, the undercutter system without conservation payment had a net return of -$34.89/2 ac/yr whereas the conventional system earned -$40.20/2 ac/yr. With conservation payments of $40.80/2 ac the undercutter system gained a positive profit of $5.91/2 ac/yr.

This farm case study suggests that adopting a soil conserving undercutter fallow tillage system may be accomplished without reducing profitability. Diminishing wind erosion with this system would protect public health and the environment in downwind areas. If conservation payments are available, profitability could be further increased relative to conventional fallow helping to motivate adoption. It should be noted that the annual conservation payment of $20/ac assumed in this study case is still less then half the typical Conservation Reserve Program rents in Adams County. Current funding is insufficient for conservation payments of this magnitude for all farmers in the study area. Future research intends to measure the precise reduction in dust emissions with the undercutter and other conservation fallow systems. This research will permit comparing the cost effectiveness (taxpayer cost per unit of dust abated) of these fallow systems to other conservation programs. This information could facilitate acquiring additional funding for conservation tillage in the wheat-fallow region of eastern Washington.

<u>Appendix</u>

Budget Tables

TABLE A1. ITEMIZED COST PER ACRE FOR SUMMER FALLOW, UNDERCUTTER METHOD, RITZVILLE, WA, 2005

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
ROUNDUP	OZ	.13	16.00	2.01	________
SURFACTANT	GL	13.00	.05	.65	________
AMM.SULFATE	OZ	.09	8.00	.72	________
AQUA-NITROGEN	LB	.34	50.00	17.00	________
SULFATE	LB	.36	5.00	1.80	________
MACHINERY FUEL/LUBE	ACRE	5.03	1.00	5.03	________
MACHINERY REPAIRS*	ACRE	2.75	1.00	2.75	________
LABOR(TRAC/MACH)	HOUR	12.00	.21	2.58	________
OVERHEAD	ACRE	1.68	1.00	1.68	________
INTEREST ON OP. CAP.	ACRE	1.08	1.00	1.08	________
TOTAL VARIABLE COST				35.31	________
FIXED COSTS		$		$	
MACHINE DEPRECIATION*	ACRE	12.23	1.00	12.23	________
MACHINE INTEREST*	ACRE	18.85	1.00	18.85	________
MACHINE INSURANCE*	ACRE	1.74	1.00	1.74	________
MACHINE TAXES*	ACRE	5.22	1.00	5.22	________
MACHINE HOUSING*	ACRE	2.90	1.00	2.90	________
LAND TAX	ACRE	5.33	1.00	5.33	________
TOTAL FIXED COST				46.27	________
TOTAL COST				81.58	________

*INCLUDING BUILDINGS, TOOLS AND TANKS.

TABLE A2. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR SUMMER FALLOW, UNDERCUT METHOD, RITZVILLE, WA, 2005

OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	VARIABLE COST: FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
UNDERCUT AT 2"	85E CHLNGR, 32' UNDERCUTTER	AUG 2004	.01	.01	.39	.50	.14	.00	.00	.01	.65	1.04
RIP	85E CHLNGR, 22' RIPPER	NOV 2004	.03	.03	1.78	1.29	.38	.00	.00	.10	1.77	3.55
SPRAY ONE	45 CHLNGR, 90' SPRAYER	MAR 2005	.01	.01	.58	.29	.16	.00	3.13(1)	.14	3.72	4.30
SPRAY TWO	45 CHLNGR, 90' SPRAYER	APR 2005	.00	.00	.11	.06	.03	.00	.25(2)	.01	.35	.47
UNDERCUT &FERTIL	85E CHLNGR, 32' UNDERCUTTER	APR 2005	.07	.08	3.09	3.47	1.00	.00	18.80(3)	.76	24.03	27.11
ROD WEED ONE	45 CHLNGR, 70' RODWEEDER	MAY 2005	.03	.03	1.34	.67	.35	.00	.00	.03	1.04	2.38
ROOD WEED TWO	45 CHLNGR, 70' RODWEEDER	JUN 2005	.03	.03	1.34	.67	.35	.00	.00	.02	1.04	2.38
ROD WEED THREE	45 CHLNGR, 70' RODWEEDER	JUL 2005	.01	.01	.67	.34	.17	.00	.00	.01	.52	1.19
MISC. USE	MACHINE SHED & SHOP BUILDING	ANN 2005	.00	.00	23.31	.28	.00	.00	.00	.01	.29	23.59
MISC. USE	SHOP TOOLS	ANN 2005	.00	.00	5.36	.17	.00	.00	.00	.01	.17	5.53
MISC. USE	FUEL & MISCELLANEOUS TANKS	ANN 2005	.00	.00	2.98	.05	.00	.00	.00	.00	.05	3.03
LAND TAXES	LAND TAXES	ANN 2005	.00	.00	5.33	.00	.00	.00	.00	.00	.00	5.33
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN 2005	.00	.00	.00	.00	.00	1.68(4)	.00	.00	1.68	1.68
TOTAL PER ACRE			.18	.21	46.27	7.78	2.58	1.68	22.19	1.08	35.31	81.58

MATERIALS:

1. 14 OZ. ROUNDUP ($1.76/AC), 0.05 GL. SURFACTANT ($0.65/AC), 8 OZ. AMM.SULFATE ($0.72/AC)
2. 2 OZ. ROUNDUP ($0.25/AC)
3. 50 LBS. AGUA-NITROGEN ($17/AC), 5 LBS. SULFATE ($1.80/AC)
4. OVERHEAD = 5% OF TOTAL VARIABLE COST

TABLE A3. ITEMIZED COST PER ACRE FOR SOFT WHITE WINTER WHEAT AFTER SUMMER FALLOW, UNDERCUT METHOD, RITZVILLE, WA, 2005

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
S.W.WHEAT SEED	LB	.13	40.00	5.32	________
PHOSPHATE	LB	.49	10.00	4.90	________
LV-6 (2,4-D ESTER)	OZ	.14	10.00	1.38	________
OLYMPUS	OZ	.09	.45	.04	________
INSURANCE WWSF	ACRE	5.00	1.00	5.00	________
MACHINERY FUEL/LUBE	ACRE	6.69	1.00	6.69	________
MACHINERY REPAIRS*	ACRE	2.47	1.00	2.47	________
LABOR(TRAC/MACH)	HOUR	12.00	.30	3.58	________
OVERHEAD	ACRE	1.49	1.00	1.49	________
INTEREST ON OP. CAP.	ACRE	.46	1.00	.46	________
TOTAL VARIABLE COST				31.33	________
FIXED COSTS		$		$	
MACHINE DEPRECIATION*	ACRE	18.34	1.00	18.34	________
MACHINE INTEREST*	ACRE	20.80	1.00	20.80	________
MACHINE INSURANCE*	ACRE	1.92	1.00	1.92	________
MACHINE TAXES*	ACRE	5.76	1.00	5.76	________
MACHINE HOUSING*	ACRE	3.32	1.00	3.32	________
SF COST + INTEREST	ACRE	86.88	1.00	86.88	________
LAND RENT**	ACRE	30.87	1.00	30.87	________
LAND TAX	ACRE	5.33	1.00	5.33	________
TOTAL FIXED COST				173.10	________
TOTAL COST				204.43	________

*INCLUDING BUILDINGS, TOOLS AND TANKS.

** 1/3 CROP – 1/3 FERTILIZER COSTS – 1/3 CROP INSURANCE – 2 YR LAND TAXES.

WHEAT YIELD IS ASSUMED TO BE 47.0 BUSHELS.
FIVE AVERAGE FARM GATE PRICE OF WHEAT IS $3.32/BUSHEL.

TABLE A4. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE SOFT WHITE WINTER WHEAT AFTER SUMMER FALLOW, UNDERCUT METHOD, RITZVILLE, WA, 2005

						VARIABLE COST							
OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
SEED & FERTILIZE	85E CHLNGR, 48' IH DRILL 7100	SEP 2004	.07	.09	3.18	2.72	1.07	.00	10.22(1)	.08	14.09	17.27
SPRAY ONE	45 CHLNGR, 90' SPRAYER	MAR 2005	.01	.01	.58	.29	.16	.00	1.42(2)	.07	1.94	2.52
HARVEST	JD 9760STS COMBINE	JUL 2005	.07	.08	9.84	3.16	.91	.00	.00	.07	4.14	13.98
HAUL WHEAT	85E CHLNGR, GRAINCART	JUL 2005	.05	.06	1.74	1.78	.72	.00	.00	.04	2.54	4.27
HAUL WHEAT	HARVEST TRUCK	JUL 2005	.05	.06	3.03	.72	.72	.00	.00	.02	1.46	4.49
SUMMER FALLOW	SUMMER FALLOW COST + INTEREST	ANN 2005	.00	.00	86.88	.00	.00	.00	.00	.00	.00	86.88
CROP INSURANCE	CROP INSURANCE	ANN 2005	.00	.00	.00	.00	.00	5.00	.00	.16	5.16	5.16
MISC. USE	MACHINE SHED & SHOP BUILDING	ANN 2005	.00	.00	23.31	.28	.00	.00	.00	.01	.29	23.59
MISC. USE	SHOP TOOLS	ANN 2005	.00	.00	5.36	.17	.00	.00	.00	.01	.17	5.53
MISC. USE	FUEL & MISCELLANEOUS TANKS	ANN 2005	.00	.00	2.98	.05	.00	.00	.00	.00	.05	3.03
LAND TAXES	LAND TAXES	ANN 2005	.00	.00	5.33	.00	.00	.00	.00	.00	.00	5.33
LAND RENT	LAND RENT (OPPORTUNITY COST)	ANN 2005	.00	.00	30.87	.00	.00	.00	.00	.00	.00	30.87
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN 2005	.00	.00	.00	.00	.00	1.49(3)	.00	.00	1.49	1.49
TOTAL PER ACRE			.25	.30	173.10	9.16	3.58	6.49	11.64	.46	31.33	204.43

MATERIALS:

1. 40 LBS. SWWW. SEED ($5.32/AC), 10 LBS. PHOSPHATE ($4.90/AC)
2. 10 OZ. LV-6 (2,4-D ESTER) ($1.38/AC), 0.45 OZ. OLYMPUS ($0.04/AC)
3. OVERHEAD = 5% OF TOTAL VARIABLE COST

TABLE A5. ITEMIZED COST PER ACRE FOR SUMMER FALLOW, CONVENTIONAL METHOD, RITZVILLE, WA, 2005

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
ROUNDUP	OZ	.13	14.00	1.76	________
SURFACTANT	GL	13.00	.05	.65	________
AMM.SULFATE	OZ	.09	8.00	.72	________
AQUA-NITROGEN	LB	.34	50.00	17.00	________
SULFATE	LB	.36	5.00	1.80	________
MACHINERY FUEL/LUBE	ACRE	5.92	1.00	5.92	________
MACHINERY REPAIRS*	ACRE	2.38	1.00	2.38	________
LABOR(TRAC/MACH)	HOUR	12.00	.23	2.76	________
OVERHEAD	ACRE	1.69	1.00	1.69	________
INTEREST ON OP. CAP.	ACRE	.89	1.00	.89	________
TOTAL VARIABLE COST				35.57	________
FIXED COSTS		$		$	
MACHINE DEPRECIATION*	ACRE	14.77	1.00	14.77	________
MACHINE INTEREST*	ACRE	20.23	1.00	20.23	________
MACHINE INSURANCE*	ACRE	1.87	1.00	1.87	________
MACHINE TAXES*	ACRE	5.60	1.00	5.60	________
MACHINE HOUSING*	ACRE	3.11	1.00	3.11	________
LAND TAX	ACRE	5.33	1.00	5.33	________
TOTAL FIXED COST				50.92	________
TOTAL COST				86.49	________

- INCLUDES BUILDINGS, TOOLS AND TANKS.

TABLE A6. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR SUMMER FALLOW, CONVENTIONAL METHOD, RITZVILLE, WA, 2005

							VARIABLE COST						
OPERATION	TOOLING	MTH	YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
						$	$	$	$	$	$	$	$
UNDERCUT AT 2"	85E CHLNGR, 32' UNDERCUTTER	AUG	2004	.01	.01	.39	.50	.14	.00	.00	.01	.65	1.04
RIP	85E CHLNGR, 22' RIPPER	NOV	2004	.03	.03	1.78	1.29	.38	.00	.00	.10	1.77	3.55
SPRAY ONE	45 CHLNGR, 90' SPRAYER	MAR	2005	.01	.01	.58	.29	.16	.00	3.13(1)	.14	3.72	4.30
CULTIVATE ONE	85E CHLNGR, 52' JD CULTIVATOR	MAR	2005	.04	.04	2.50	1.64	.53	.00	.00	.08	2.25	4.75
CULTIVATE TWO	85E CHLNGR, 52' JD CULTIVATOR	APR	2005	.04	.04	2.50	1.64	.53	.00	.00	.07	2.24	4.74
FERTILIZE	85E CHLNGR, 60' CULTER WEEDER	JUN	2005	.03	.04	4.18	1.43	.50	.00	18.80(2)	.45	21.18	25.36
ROD WEED ONE	45 CHLNGR, 70' RODWEEDER	JUN	2005	.03	.03	1.34	.67	.35	.00	.00	.02	1.04	2.38
ROD WEED TWO	45 CHLNGR, 70' RODWEEDER	JUL	2005	.01	.01	.67	.34	.17	.00	.00	.01	.52	1.19
MISC. USE	MACHINE SHED & SHOP BUILDING	ANN	2005	.00	.00	23.31	.28	.00	.00	.00	.01	.29	23.59
MISC. USE	SHOP TOOLS	ANN	2005	.00	.00	5.36	.17	.00	.00	.00	.01	.17	5.53
MISC. USE	FUEL & MISCELANEOUS TANKS	ANN	2005	.00	.00	2.98	.05	.00	.00	.00	.00	.05	3.03
LAND TAXES	LAND TAXES	ANN	2005	.00	.00	5.33	.00	.00	.00	.00	.00	.00	5.33
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN	2005	.00	.00	.00	.00	.00	1.69(3)	.00	.00	1.69	1.69
TOTAL PER ACRE				.20	.23	50.92	8.30	2.76	1.69	21.93	.89	35.57	86.49

MATERIALS:

1. 14 OZ. ROUNDUP ($1.76/AC), 0.05 GL. SURFACTANT ($0.65/AC), 8 OZ. AMM.SULFATE ($0.72/AC)
2. 50 LBS. AQUA-NITROGEN ($17/AC), 5 LBS. SULFATE ($1.80/AC)
3. OVERHEAD = 5% OF TOTAL VARIABLE COST

TABLE A7. ITEMIZED COST PER ACRE FOR SOFT WHITE WINTER WHEAT AFTER SUMMER FALLOW, CONVENTIONAL METHOD, RITZVILLE, WA, 2005

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
S.W.WHEAT SEED	LB	.13	40.00	5.32	________
PHOSPHATE	LB	.49	10.00	4.90	________
LV-6 (2,4-D ESTER)	OZ	.14	10.00	1.38	________
OLYMPUS	OZ	.09	.45	.04	________
INSURANCE WWSF	ACRE	5.00	1.00	5.00	________
MACHINERY FUEL/LUBE	ACRE	6.69	1.00	6.69	________
MACHINERY REPAIRS*	ACRE	2.47	1.00	2.47	________
LABOR(TRAC/MACH)	HOUR	12.00	.30	3.58	________
OVERHEAD	ACRE	1.49	1.00	1.49	________
INTEREST ON OP. CAP.	ACRE	.46	1.00	.46	________
TOTAL VARIABLE COST				31.32	________
FIXED COSTS		$		$	
MACHINE DEPRECIATION*	ACRE	18.34	1.00	18.34	________
MACHINE INTEREST*	ACRE	20.80	1.00	20.80	________
MACHINE INSURANCE*	ACRE	1.92	1.00	1.92	________
MACHINE TAXES*	ACRE	5.76	1.00	5.76	________
MACHINE HOUSING*	ACRE	3.20	1.00	3.20	________
SF COST + INTEREST	ACRE	92.11	1.00	92.11	________
LAND RENT**	ACRE	30.96	1.00	30.96	________
LAND TAX	ACRE	5.33	1.00	5.33	________
TOTAL FIXED COST				178.42	________
TOTAL COST				209.74	________

*INCLUDING BUILDINGS, TOOLS AND TANKS.

** 1/3 CROP – 1/3 FERTILIZER COSTS – 1/3 CROP INSURANCE – 2 YR LAND TAXES.

WHEAT YIELD IS ASSUMED TO BE 47.0 BUSHELS.
FIVE AVERAGE FARM GATE PRICE OF WHEAT IS $3.32/BUSHEL.

TABLE A8. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE SOFT WHITE WINTER WHEAT AFTER SUMMER FALLOW, CONVENTIONAL METHOD, RITZVILLE, WA, 2005

						VARIABLE COST						
OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
SEED & FERTILIZE	85E CHLNGR, 48' IH DRILL 7100	SEP 2004	.07	.09	3.18	2.72	1.07	.00	10.22(1)	.08	14.09	17.27
SRAY ONE	45 CHLNGR, 90' SPRAYER	MAR 2005	.01	.01	.58	.29	.16	.00	1.42(2)	.07	1.94	2.52
HARVEST	JD 9760STS, COMBINE	JUL 2005	.07	.08	9.84	3.16	.91	.00	.00	.07	4.14	13.98
HAUL WHEAT	85E CHLNGR, GRAINCART	JUL 2005	.05	.06	1.74	1.78	.72	.00	.00	.04	2.54	4.27
HAUL WHEAT	HARVEST TRUCK	JUL 2005	.05	.06	3.03	.72	.72	.00	.00	.02	1.46	4.49
SUMMER FALLOW	SUMMER FALLOW COST + INTEREST	ANN 2005	.00	.00	92.11	.00	.00	.00	.00	.00	.00	92.11
CROP INSURANCE	CROP INSURANCE	ANN 2005	.00	.00	.00	.00	.00	5.00	.00	.16	5.16	5.16
MISC. USE	MACHINE SHED & SHOP BUILDING	ANN 2005	.00	.00	23.31	.28	.00	.00	.00	.01	.29	23.59
MISC. USE	SHOP TOOLS	ANN 2005	.00	.00	5.36	.17	.00	.00	.00	.01	.17	5.53
MISC. USE	FUEL & MISCELLANEOUS TANKS	ANN 2005	.00	.00	2.98	.05	.00	.00	.00	.00	.05	3.03
LAND TAXES	LAND TAXES	ANN 2005	.00	.00	5.33	.00	.00	.00	.00	.00	.00	5.33
LAND RENT	LAND RENT (OPORTUNITY COST)	ANN 2005	.00	.00	30.96	.00	.00	.00	.00	.00	.00	30.96
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN 2005	.00	.00	.00	.00	.00	1.49	.00	.00	1.49	1.49
TOTAL PER ACRE			.25	.30	178.42	9.15	3.58	6.49	11.64	.46	31.32	209.74

MATERIALS:

1. 40 LBS. SWWW SEED ($5.32/AC), 10 LBS. PHOSPHATE ($4.90/AC)
2. 10 OZ. LV-6 (2,4-D ESTER) ($1.38/AC), 0.45 OZ. OLYMPUS ($0.04/AC)
3. OVERHEAD = 5% OF TOTAL VARIABLE COST

TABLE A9. PER HOUR AND PER ACRE MACHINERY COSTS, UNDERCUTTER AND CONVENTIONAL TILLAGE, RITZVILLE, WA, 2005

MACHINERY	PURCHASE PRICE	YEARS TO TRADE	ANNUAL HOURS	DEPREC-IATION	INTER-EST	INSUR-ANCE	TAXES	HOUSING	TOTAL FIXED COST	REPAIR	FUEL AND LUBE	TOTAL VARIABLE COST	TOTAL COST
	$			COST PER HOUR									
85E CHALL. 375HP	150,000.00	7	1000	12.14	6.99	.65	1.94	1.08	22.79	2.25	32.06	34.31	57.09
45 CHALLEN 200HP	125,000.00	7	1000	7.14	6.50	.60	1.80	1.00	17.04	.94	21.37	22.31	39.35
JD9760STS-325HP	200,000.00	3	300	90.00	34.56	3.19	9.57	5.32	142.64	18.00	27.78	45.78	188.42
30'JD2200 CULTIV	45,000.00	10	144	17.36	14.67	1.35	4.06	2.26	39.70	6.74	.00	6.74	46.45
IH 7100,48'DRILL	25,000.00	10	144	9.03	8.35	.77	2.31	1.28	21.75	3.76	.00	3.76	25.51
HARVEST TRUCK	30,000.00	7	72	29.76	20.31	1.88	5.63	3.13	60.70	1.50	12.82	14.32	75.02
GRAIN CART	25,000.00	10	250	4.00	5.20	.48	1.44	.80	11.92	1.25	.00	1.25	13.17
CALKINS TANKCART	12,000.00	10	221	3.17	2.50	.23	.69	.38	6.98	1.80	.00	1.80	8.77
60'CULTER WEEDER	35,000.00	10	46	54.35	31.79	2.93	8.80	4.89	102.77	8.70	.00	8.70	111.47
CALKINS RODWEEDR	20,500.00	15	67	12.94	13.58	1.25	3.76	2.09	33.62	3.09	.00	3.09	36.71
22'RIPPER	28,000.00	10	88	20.45	14.03	1.30	3.89	2.16	41.83	12.64	.00	12.64	54.47
90' SPRAYER 2005	27,000.00	10	108	20.37	9.63	.89	2.67	1.48	35.04	4.05	.00	4.05	39.08
32' UNDERCUTTER	32,000.00	15	212	6.29	6.75	.62	1.87	1.04	16.56	16.02	.00	16.02	32.59
			ACRES COVERED	COST PER ACRE									
FARM BUILDING	300,000.00	40	1085	4.15	12.58	1.16	3.48	1.94	23.31	.28	.00	.28	23.59
SHOP TOOLS	45,000.00	10	1085	2.49	1.89	.17	.52	.29	5.36	.17	.00	.17	5.53
FUEL &MISC TANKS	25,000.00	10	1085	1.38	1.05	.10	.29	.16	2.98	.05	.00	.05	3.03

TABLE A10. ITEMIZED COST PER ACRE FOR SUMMER FALLOW, MIN-TILL METHOD, RITZVILLE, WA, 2005

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
AQUA-NITROGEN	LB	.34	60.00	20.40	________
MACHINERY FUEL/LUBE	ACRE	3.96	1.00	3.96	________
MACHINERY REPAIRS*	ACRE	4.52	1.00	4.52	________
LABOR(TRAC/MACH)	HOUR	12.00	.49	5.88	________
OVERHEAD	ACRE	1.78	1.00	1.78	________
INTEREST ON OP. CAP.	ACRE	.92	1.00	.92	________
TOTAL VARIABLE COST				37.48	________
FIXED COSTS		$		$	
MACHINE DEPRECIATION*	ACRE	4.95	1.00	4.95	________
MACHINE INTEREST*	ACRE	5.84	1.00	5.84	________
MACHINE INSURANCE*	ACRE	.53	1.00	.53	________
MACHINE TAXES*	ACRE	1.61	1.00	1.61	________
MACHINE HOUSING*	ACRE	.90	1.00	.90	________
LAND TAX	ACRE	4.92	1.00	4.92	________
TOTAL FIXED COST				18.75	________
TOTAL COST				56.23	________

* INCLUDES BUILDINGS, TOOLS AND TANKS.

TABLE A11. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR SUMMER FALLOW, MIN-TILL METHOD, RITZVILLE, WA, 2005

OPERATION	TOOLING	MTH YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	VARIABLE COST: FUEL, LUBE, & REPAIRS	VARIABLE COST: MACH LABOR	VARIABLE COST: SERVICE	VARIABLE COST: MATER.	VARIABLE COST: INTER.	TOTAL VARIABLE COST	TOTAL COST
					$	$	$	$	$	$	$	$
FALL HARROW	CHLNGR 45, 72' HARROW	SEP 2004	.02	.02	.41	.32	.21	.00	.00	.00	.53	.94
FALL CHISEL	CHLNGR 45, 28' CHISEL	OCT 2004	.06	.06	1.05	1.15	.74	.00	.00	.00	1.89	2.94
SPRING SPRAY	CHLNGR 45, 90' SPRAYER	MAR 2005	.02	.02	.31	.33	.20	.00	.00	.02	.55	.86
CULTIVATE,ROTARY	CULTIVATE W/ROTARY HOE,CHLNG45	MAY 2005	.07	.08	.78	1.03	.96	.00	20.40(1)	.61	23.00	23.78
ROD WEED ONE	CHLNGR 45, 72' RODWEEDER	JUN 2005	.02	.02	.26	.39	.25	.00	.00	.01	.65	.91
ROD WEED TWO	CHLNGR 45, 72' RODWEEDER	JUL 2005	.02	.02	.26	.39	.25	.00	.00	.01	.65	.91
MISC. USE	FARM BUILDINGS	ANN 2005	.00	.00	4.91	.92	.00	.00	.00	.03	.95	5.86
MISC. USE	SHOP TOOLS	ANN 2005	.00	.00	3.19	.46	.00	.00	.00	.01	.48	3.66
MISC. USE	FUEL & MISCELLANEOUS TANKS	ANN 2005	.00	.00	.46	.09	.00	.00	.00	.00	.10	.55
MISC. USE	79 IH TRUCK 3500 GVW	ANN 2005	.08	.08	.61	1.20	.96	.00	.00	.07	2.23	2.84
MISC. USE	79 IH 2150 TRUCK 2900 GVW	ANN 2005	.09	.10	.85	1.52	1.20	.00	.00	.09	2.81	3.66
MISC. USE	JD 5310 UTILITY TRACTOR	ANN 2005	.05	.06	.54	.40	.72	.00	.00	.04	1.15	1.69
MISC. USE	1973 CHEVY PICKUP	ANN 2005	.03	.03	.22	.30	.38	.00	.00	.02	.71	.92
LAND TAXES	LAND TAXES	ANN 2005	.00	.00	4.92	.00	.00	.00	.00	.00	.00	4.92
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN 2005	.00	.00	.00	.00	.00	1.78(2)	.00	.00	1.78	1.78
TOTAL PER ACRE			.45	.49	18.75	8.49	5.88	1.78	20.40	.92	37.48	56.23

MATERIALS:

1. 60 LBS. AGUA-NITROGEN ($20.40/AC)
2. OVERHEAD = 5% OF TOTAL VARIABLE COST

TABLE A12. ITEMIZED COST PER ACRE FOR SOFT WHITE WINTER WHEAT AFTER SUMMER FALLOW, MIN-TILL METHOD, RITZVILLE, WA, 2005

	UNIT	PRICE OR COST/UNIT	QUANTITY	VALUE OR COST	YOUR FARM
VARIABLE COSTS		$		$	
SWWW SEED	LB	.13	50.00	6.65	________
LV-6 (2,4-D ESTER)	OZ	.14	24.00	3.31	________
SURFACTANT	GL	13.00	.05	.65	________
RENT HRVST COMB	ACRE	14.50	1.00	14.50	________
INSURANCE WWSF	ACRE	4.49	1.00	4.49	________
MACHINERY FUEL/LUBE	ACRE	5.33	1.00	5.33	________
MACHINERY REPAIRS*	ACRE	11.21	1.00	11.21	________
LABOR(TRAC/MACH)	HOUR	12.00	.61	7.38	________
OVERHEAD	ACRE	2.73	1.00	2.73	________
INTEREST ON OP. CAP.	ACRE	1.09	1.00	1.09	________
TOTAL VARIABLE COST				57.35	________
FIXED COSTS		$		$	
MACHINE DEPRECIATION*	ACRE	9.13	1.00	9.13	________
MACHINE INTEREST*	ACRE	10.17	1.00	10.17	________
MACHINE INSURANCE*	ACRE	.94	1.00	.94	________
MACHINE TAXES*	ACRE	2.81	1.00	2.81	________
MACHINE HOUSING*	ACRE	1.56	1.00	1.56	________
SF COST+INTERST	ACRE	59.88	1.00	59.88	________
LAND RENT**	ACRE	15.62	1.00	15.62	________
LAND TAX	ACRE	4.92	1.00	4.92	________
TOTAL FIXED COST				105.03	________
TOTAL COST				162.38	________

* INCLUDES BUILDINGS, TOOLS AND TANKS.

** 1/3 CROP – 1/3 FERTILIZER COSTS – 1/3 CROP INSURANCE – 2 YR LAND TAXES.

WHEAT YIELD IS ASSUMED TO BE 30.5 BUSHELS.
FIVE AVERAGE FARM GATE PRICE OF WHEAT IS $3.32/BUSHEL.

TABLE A13. SCHEDULE OF OPERATIONS AND ESTIMATED COSTS PER ACRE FOR SOFT WHITE WINTER WHEAT AFTER SUMMER FALLOW, MIN-TILL METHOD, RITZVILLE, WA, 2005

							VARIABLE COST						
OPERATION	TOOLING	MTH	YEAR	MACH HOURS	LABOR HOURS	TOTAL FIXED COST	FUEL, LUBE, & REPAIRS	MACH LABOR	SERVICE	MATER.	INTER.	TOTAL VARIABLE COST	TOTAL COST
						$	$	$	$	$	$	$	$
SEED	45 CHLNGR, 48' IH DRILL 150	SEP	2004	.03	.04	.70	.68	.46	.00	6.65(1)	.04	7.83	8.53
SPRAY BRADLEAF	45 CHLNGR, 90' SPRAYER	MAR	2005	.02	.02	.31	.33	.20	.00	3.96(2)	.17	4.67	4.98
HARVEST OWN COMB	79 GLEANER MHZ (OWN COMBINE)	JUL	2005	.15	.20	12.82	10.66	2.40	.00	.00	.21	13.27	26.09
HARVEST RENT COM	CIH 2188 COMBINE (RENTED)	JUL	2005	.00	.09	.00	.00	1.05	14.50	.00	.25	15.80	15.80
CROP INSURANCE	CROP INSURANCE	ANN	2005	.00	.00	.00	.00	.00	4.49	.00	.15	4.64	4.64
SUMMER FALLOW	SUMMER FALLOW COST + INTEREST	ANN	2005	.00	.00	59.88	.00	.00	.00	.00	.00	.00	59.88
MISC. USE	FUEL & MISCELLANEOUS TANKS	ANN	2005	.00	.00	.46	.09	.00	.00	.00	.00	.10	.55
MISC. USE	79 IH 2150 TRUCK 2900 GVW	ANN	2005	.09	.10	.85	1.52	1.20	.00	.00	.09	2.81	3.66
MISC. USE	1973 CHEVY PICKUP	ANN	2005	.03	.03	.22	.30	.38	.00	.00	.02	.71	.92
MISC. USE	FARM BUILDINGS	ANN	2005	.00	.00	4.91	.92	.00	.00	.00	.03	.95	5.86
MISC. USE	79 IH TRUCK 3500 GVW	ANN	2005	.08	.08	.61	1.20	.96	.00	.00	.07	2.23	2.84
MISC. USE	SHOP TOOLS	ANN	2005	.00	.00	3.19	.46	.00	.00	.00	.01	.48	3.66
MISC. USE	JD 5310 UTILITY TRACTOR	ANN	2004	.05	.06	.54	.40	.72	.00	.00	.04	1.15	1.69
LAND TAXES	LAND TAXES	ANN	2005	.00	.00	4.92	.00	.00	.00	.00	.00	.00	4.92
LAND RENT	LAND RENT (OPPORTUNITY COST)	ANN	2005	.00	.00	15.62	.00	.00	.00	.00	.00	.00	15.62
OVERHEAD	UTILITIES, LEGAL, ACCT., ETC.	ANN	2005	.00	.00	.00	.00	.00	2.73(3)	.00	.00	2.73	2.73
TOTAL PER ACRE				.45	.61	105.03	16.55	7.38	21.72	10.61	1.09	57.35	162.38

MATERIALS:

1. 50 LBS. SWWW SEED ($6.65/AC)
2. 24 OZ. LV-6 (2,4-D ESTER) ($3.31/AC), 0.05 GL. SURFACTANT ($0.65/AC)
3. OVERHEAD = 5% OF TOTAL VARIABLE COST

TABLE A14. PER HOUR AND PER ACRE MACHINERY COSTS, MIN-TILL, RITZVILLE, WA, 2005

MACHINERY	PURCHASE PRICE	YEARS TO TRADE	ANNUAL HOURS	DEPRECIATION	INTEREST	INSURANCE	TAXES	HOUSING	TOTAL FIXED COST	REPAIR	FUEL AND LUBE	TOTAL VARIABLE COST	TOTAL COST
	$			COST PER HOUR									
45 CHALLEN.225HP	48,000.00	15	550	4.00	3.72	.34	1.03	.57	9.67	4.55	10.69	15.23	24.90
72' HARROW	6,000.00	20	40	5.63	6.09	.56	1.69	.94	14.91	3.75	.00	3.75	18.66
28' CHISEL	7,500.00	45	70	2.06	3.95	.36	1.09	.61	8.07	4.29	.00	4.29	12.36
90' SPRAYER	9,000.00	30	80	1.67	5.69	.53	1.58	.88	10.33	6.25	.00	6.25	16.58
CULTVTR.& ROT.HOE	4,000.00	28	200	.18	1.46	.14	.41	.23	2.05	.25	.00	.25	2.30
72' RODWEEDER	4,000.00	35	120	.24	1.90	.18	.53	.29	3.13	4.17	.00	4.17	7.29
48' DRIL (IH150)	10,000.00	57	80	.55	7.11	.66	1.97	1.09	11.38	5.00	.00	5.00	16.38
79 GLEANER COMBN	50,000.00	30	50	32.33	33.48	3.09	9.27	5.15	83.32	50.00	19.24	69.24	152.55
TRUCK 3500 GUW	8,000.00	25	100	1.40	4.06	.38	1.13	.63	7.59	7.50	7.48	14.98	22.57
TRUCK 2900 GUW	8,000.00	25	80	1.75	5.08	.47	1.41	.78	9.48	9.38	7.48	16.86	26.34
JD5310UTIL.TRCTR	25,000.00	32	200	2.73	5.28	.49	1.46	.81	10.78	1.50	6.41	7.91	18.69
73 CHEVY PICKUP	6,500.00	52	70	1.24	3.95	.36	1.09	.61	7.25	1.43	8.55	9.98	17.22
			ACRES COVERED	COST PER ACRE									
FARM BUILDINGS	62,000.00	30	1085	1.54	2.22	.20	.61	.34	4.91	.92	.00	.92	5.83
SHOP TOOLS	30,000.00	15	1085	1.75	.94	.09	.26	.15	3.19	.46	.00	.46	3.65
FUEL &MISC TANKS	6,000.00	30	1085	.18	.18	.02	.05	.03	.46	.09	.00	.09	.55

Table A15: Input and Commodity Price List, 2005

Material	**Unit**	**Price ($/unit)**
Seed[1]		
Soft White Winter Wheat, Registered	Pound	0.133
Chemicals[2]		
Ammonia Sulfate	Ounce	0.09
Aqua - Nitrogen	Pound	0.34
Phosphate (P_2O_5)	Pound	0.49
Sulfate (S)	Pound	0.36
Round-Up	Ounce	0.126
2,4-D, LV-6	Ounce	0.138
Olympus	Ounce	0.086
Surfactants	Gallon	13.00
Other Costs[3]		
Diesel[4]	Gallon	1.94
Interest Rate	Percent	6.5
Machinery Labor	Hour	12.00
Crop Insurance	Acre	5.00
Land Tax	Acre	5.33
Commodity Prices (5-year average)		
Soft White Winter Wheat[5]	Bushel	3.32

[1]Seed price was provided by the farmer.

[2]Chemical input prices were supplied by the farmer.

[3]Cost of crop insurance and land tax were provided by the farmer.

[4]Excluding road taxes.

[5]Five-year average farm gate price of wheat from Lind, WA elevator.

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PART 2

ECONOMICS OF WATER AND LAND RESOURCE ALLOCATION UNDER THE STATE ORDER REQUIREMENTS ON THE EXAMPLE OF NAMANGAN REGION, UZBEKISTAN

Summary

This study evaluates the production activities of a 20-hectare irrigated farm in the Namangan region of Uzbekistan. The farm operates with a limited amount of water and land. The farm has only two crop enterprises, cotton and wheat, that are irrigated by a conventional furrow system. Other furrow irrigation techniques (every other furrow, surge and discrete irrigation) that have higher irrigation efficiency were later introduced and analyzed in this study. The government orders production of these crops and most of the yield has to be sold to the government agency at prices that are lower then world market price.

The objective of this study is to examine the economics of land and water use and to predict how farm income and the pattern of agricultural activity will change as the farm

responds to water shortages or price changes. Mathematical linear programming (LP) models are used to determine optimal water and land use changes by either more efficient irrigation techniques, reducing acreage in the two crops, or irrigating with less than full Net Irrigation Requirement (NIR). Several scenarios were examined based on variation in water supply in the most critical period and in the prices of labor.

The study shows that farmers can expect to earn higher incomes when they grow more cotton even without any government determination of what to grow. The results of the model shows that adopting improved irrigation methods improving field irrigation efficiency would allow farmers to not only minimize the effect of water shortage but also to achieve higher yield and consequently higher net farm returns for both of these crops.

Background of Agriculture in Uzbekistan

Agriculture is the largest sector in the economy of Uzbekistan and accounted for 31% of the gross domestic product (GDP) in 2004. More than 50% of the population lives in rural communities and is involved in agriculture (The World Bank, 2004).

Climate in Uzbekistan is classified as continental and is quite arid, with hot summers and cool winters. Summer temperatures often surpass 40°C. The average annual rainfall amounts only to between 100 and 200 millimeters and occurs mostly in winter and spring.

Between July and September; little precipitation falls, essentially stopping the growth of vegetation during that critical period.

Irrigation is vital for agriculture in Uzbekistan. More than 80% of farmed land is irrigated and more then 90% of crop production is from irrigated land. Irrigated agriculture accounts for 90% of water consumption in Uzbekistan where most water use is in the vegetative period (FAO, 2002). The World Bank (2002) estimated that 60% of water resources in Central Asia are consumed by agriculture in Uzbekistan. Taking into account the dry climate and low level of precipitation, water is the most critical resource in this region. Therefore, irrigation water supply and management are the major factors in agricultural production. It is well known that all plants depend on an adequate water supply for optimum growth and development. In Uzbekistan, and many irrigated areas, water shortage mainly occurs during the summer, when failure to meet full requirements causes the greatest damage to the plant and decrease in yield for many crops.

Conventional furrow irrigation is the most common method in Uzbekistan. It has a low level of field irrigation efficiency (50-55%). Irrigation system costs are heavily subsidized by the government and water use is not metered. Substantial water losses occur in the on-farm irrigation system and in the field. According to the Water Use and Farm Management Survey (WUFMAS) under TACIS project (SIC/IWMI, 2002), the conveyance losses usually reach 37% from the total volume of water supplied to the farm and 21% of water is lost in the field. The World Bank reports that on average farmers in Uzbekistan use 14,000 m^3/ha for irrigation of cotton, while other countries with similar climate condition, such as Pakistan and Egypt, use only 9,000-10,000 m^3/ha (The World Bank, 2000).

Meanwhile poor management and declining technical conditions of irrigation infrastructure are reducing the capacity for water delivery to the farm.

Agriculture in Uzbekistan is mostly geared to the production of cotton and wheat. Cotton production has fallen after independence (1991) due to declining yield, from 25 centner/ha (10 centners = 1 metric ton) in 1990 to 22 centner/ha in 2003 (The World Bank, 2005). There has been a substantial expansion in the grain area and production is encouraged to substitute for grain imports. Thirty percent of cotton land was reallocated for wheat production. Cotton and wheat together account for about 70% of the area under cultivation. The government generally specifies which crops will be grown on what land, providing farms with inputs at subsidized prices. Farmers also have to sell half of their wheat and the whole of their cotton to the government agency at a state-determined price that is generally below world market value. As a result of this disincentive, the production of cotton and grain is not at the economic efficient point and is likely below potential. Hence, it is desirable to change policy to promote market-oriented reforms in the agricultural sector, and liberalize access to inputs and markets for output (The World Bank, 2004).

As a result of implementation of the program of economical reforms and development of multi-structural agricultural production, collective and state farms were reorganized into three new forms of ownership: *shirkat* (cooperative), private and *dekhkan* farm. *Shirkat* (cooperative) farm is a large-scale production unit that is a successor of the collective farms of the past. Basically, it is a cooperative enterprise consisting of many subunits that lease the land to *shirkat*'s members (*pudrats*) for agricultural activity. Currently incentives within the collective farms remain poor because the state is imposing fixed quotas for agricultural land under cotton and wheat cultivation. Besides, the profit sharing arrangements in *shirkats* limit their productivity as efficient *shirkat*'s members (*pudrats*) have little financial autonomy and cover the losses of less efficient ones. Currently the government is reorganizing all unprofitable *shirkats* into private farms that have stronger production incentives then *shirkats*. In 2005, the process of transformation from *shirkats* into private farms is accelerating and the government intends to reorganize 55% of unprofitable *shirkats* into private farms and about 20% of the cultivated land has already been transferred to private farms (Khan, 2005).

The private farms are commercially oriented, but they are much smaller then *shirkats*. The minimum size is 10 ha for cotton and wheat farm and 1 ha for horticulture or orchard crops farm. Private farms have a leasehold tenure for minimum 10 year and a maximum of 49 years, with the possibility to be renewed. Private farmers are allowed to hire labor. However, these farms are also subject to mandatory cropping plans and state procurement of their production at state-determined prices (The World Bank, 2003). Therefore, the private farm system also results in inefficient land use and choice of crops.

Dekhkan (peasant) farms, concentrating on personal plots of households, have been increased substantially by endowing them with more land. Only family members may be employed on *dekhkan* farms. According to the law about *dekhkan* farms, the size of *dekhkan* land is 0.35 ha for irrigated land, 0.5 ha for non-irrigated and 1 ha for pasture. The land is the subject to lifelong heritable tenure. These farms are free to sell their products on the market, and they are not subject to state directive, which allows them to be more productive.

However, they are constrained by insufficient access to land and inputs and consequently have difficulty to increasing productivity and family income.

Considering the experience of other countries that have faced the same water management problems in the past, the government took steps toward organizing Water Users Associations (WUA). They are created on the territory of former collective and state farms and *shirkat* (cooperative) farms. The WUA receives water from the state water agency and supplies water to water users, charging some fee to cover the costs of this service. The objective of this institution is to provide incentives for more efficient water use by passing water management responsibilities to water users and introducing more self-regulated mechanism for operating, maintaining, and repairing irrigation and drainage systems. One of the main functions of WUAs is to deliver water directly to the fields of water users in a way that reduces conflicts among neighbors.

The land of private farms in the WUA continues to be under state ownership and there is no private land market. It is written in the Constitution of the Republic of Uzbekistan that it is not allowed to sell land to a private owner. However, long-term leases are permitted with the following right of inheritance. The unclear land ownership does not give farmers an assurance that their land rights are protected. Solving these issues would stimulate and motivate farmers to achieve better production results and to use water and land resources more efficiently.

The government retains control over production/planting, procurement and pricing of strategic crops - cotton and wheat - which account for 70 percent of cultivated land (The World Bank, 2003). Farmers have little power to make decisions over what to grow and whom to sell to. Farmers use production factors based on pre-determined production objectives and not on marginal cost considerations. The centralized system of land and water use with fixed quotas for crop production and centrally assigned water continue to impose major constraints to achieve their efficient use. The administrative requirements hamper efficient and sustainable use of land and water.

Currently water is provided free by the state's distribution agencies. Irrigation water use per hectare is much higher compared to other regions, e.g. in Turkey and Egypt where similar climatic conditions exist. Also, the yields of main crops (cotton and wheat) are reported to be one-third of what is produced elsewhere. The introduction of water charges would create incentives to save water and improve the situation with land and water resources and the environment.

Model & Methodology

Farm Characteristics

A farm planning model was developed in order to analyze optimal irrigation scheduling and crop pattern planning under adequate and deficit water supply conditions. Namangan region was selected as a study area for this research. It is located in the northern part of the Fergana Valley in the far eastern part of the country. It is on the right bank of Syr Darya River and borders with Kyrgyzstan, and the Fergana and Andijan regions of Uzbekistan. Namangan covers 7,900 sq. km (see figure 1). This region is densely populated and has a high level of unemployment. The population is estimated to be around 1,862,000, with over 62% of the population living in rural areas.

Namangan region includes 265,000 ha of irrigated agricultural land. Irrigation water is supplied from the Syr Darya River via systems of channels and pumps and often reaches the fields in open and unlined channels. The region consumes 3,330 million m^3 of water for agricultural use.

Figure 1. Site of Namangan Region, Uzbekistan.

The area planted to cotton and wheat, the main crops, is required by state order. Vegetable and fruit production generally occurs in small plots (usually less then 0.5 ha.) for the farm family’s consumption or for selling on the market to bring some additional income to their household. Almost all farms furrow irrigate with traditional technology and moderate to low efficiency. Some areas and farms that experience water shortage make an effort to improve efficiency with different irrigation methods.

The model was developed for a farm size of 20 ha., growing cotton and wheat. According to the law, farmers are required to grow cotton and wheat on their land, with the amount depending on the region and fertility of soil. It was assumed that there is a requirement for the model farm to grow at least 8 ha. of cotton and 6 ha. of winter wheat with some flexibility to choose between the two on the remaining 6 ha.

Crop Water Requirements

Water requirements of cotton and wheat were estimated for each of 4 stages (initial, crop development, mid-season and late) based on the study of Doorenboos and Kassam (FAO web-site, 2006). Table 1 displays the periods and their dates for sowing, growing stages and harvesting for winter wheat and cotton.

Table 1. Periods and crop growing stages.

		Stages	
	Time Period	Cotton[a]	Wheat[b]
Period 0	10/28 - 11/27	----	Initial
Period 1	11/28 - 4/14	----	Crop Development
Period 2	4/15 - 5/15	Initial	Midseason
Period 3	5/16 - 6/30	Crop Development	Late
Period 4	7/1 - 8/30	Midseason	----
Period 5	9/1 - 10/27	Late	----

[a]Farmers seed cotton on April 15 and harvest before October 27.
[b]Farmers seed winter wheat on October 28 and harvest before June 30.

Crop water requirements are satisfied by effective rain and water that is supplied by irrigation to supplement the rainfall. The amount of irrigation water needed to meet crop water requirements is known as net irrigation requirements (NIR). Addition of irrigation water lost to non-beneficial evapotranspiration and drainage brings the total to what is known as field irrigation requirements (FIR). FIR equals NIR divided by field efficiency. Field irrigation efficiency generally refers to the fraction of the water volume applied to a field that is "consumed" by a crop, relative to the amount applied (FAO, 1997).

Irrigation requirements for all periods for each crop were calculated by using the CROPWAT program. CROPWAT was developed by the Land and Water Development Division of FAO (FAO I&D. Paper 46, 1992). The evapotranspiration (ET) concept is used by CROPWAT to calculate reference evapotranspiration, crop water requirements, and crop irrigation requirements. It is also used to develop irrigation schedules under various management conditions and to evaluate production and drought effects and efficiency of irrigation practices.

Evapotranspiration (ET) is the principal concept in estimating yield-water relationships. Evapotranspiration includes two bio-physical processes: evaporation and transpiration. Evaporation is the process by which liquid water is transferred into water vapor and evaporates from the surface (soil, lake, river, etc.) into the atmosphere. Transpiration is the plant-related process that vaporizes liquid water from plants and evaporates it into the atmosphere. However, it is very hard to distinguish this process because both happen simultaneously and one might be more involved than the other, depending on the stage of growth. For example, at the early stage, soil evaporation is the main source of water loss from a field, but, once the crop is well developed and plants cover the soil, transpiration becomes the main process.

FAO Irrigation and Drainage Paper No. 56 states that "at sowing nearly 100% of ET comes from evaporation, while at full crop cover more than 90% of ET comes from transpiration" (FAO I&D Paper No. 56, 1998). The amount of water required to compensate for evapotranspiration loss from the cropped field is defined as crop water requirement. The values for crop evapotranspiration and crop water requirement are identical; however, crop water requirement refers to the amount of water that needs to be supplied, while crop evapotranspiration refers to the amount of water that is lost through evapotranspiration (Allen et al, 1999).

The procedures for calculating crop water requirements and irrigation requirements are described in FAO Irrigation and Drainage Papers No. 56 "Crop evapotranspiration" and No. 33 "Yield response to water". This methodology provides a way to calculate crop water productivity under adequate and deficit water supply.

Table 2. Net Irrigation Requirements (NIR) and Field Irrigation Requirements (FIR) per hectare for conventional furrow irrigation by periods and total.

		Cotton		**Winter Wheat**	
	Time Period	**NIR, m^3**	**FIR[a], m^3**	**NIR, m^3**	**FIR[a], m^3**
Period 0	10/28 - 11/27	0	0	198.8	375
Period 1	11/28 - 4/14	0	0	169.1	319
Period 2	4/15 - 5/15	37.4	70.5	1 035.6	1954
Period 3	5/16 - 6/30	1581.3	2983.5	1 999.7	3773
Period 4	7/1 - 8/30	3407.8	6429.75	0	0
Period 5	9/1 - 10/27	1210.8	2284.5	0	0
TOTAL:		**6237.2**	**11768.3**	**3403.1**	**6421.0**

[a]Field Irrigation Efficiency of 53% is used in base activities for the model.

CROPWAT requires the climate (mean monthly temperature, precipitation, humidity, wind speed, duration of sunshine) and crop data to calculate crop water and irrigation requirements. Climate information for Namangan region, Uzbekistan was obtained from the CLIMWAT climate database (I&D Paper 49, 1993). The NIR and FIR estimated by CROPWAT are presented for each of six periods in table 2.

The yield response to water is established using the relationship between relative yield (Y_a/Y_m) and relative water consumption (ET_a/ET_m) established by Doorenboos and Kassam (1979):

$$Y_a / Y_m = 1 - K_y * (1 - ET_a / ET_m)$$

where

Y_a : actual yield (kg/ha)

Y_m : maximum yield (kg/ha)

ET_a : actual water consumption (mm or m3)

ET_m : maximum water consumption (mm or m3)

K_y : the yield response factor, varies depending on type and development phase of the plants and shows whether a plant is sensitive to water in the specific period.

FAO Irrigation and Drainage Papers No. 33 "Yield response to water" provides the yield response factor for the total growing season and individual growth stages for several crops (FAO I&D Paper No. 33, 1979). The yield factors were slightly modified for this study after consultation with agronomists and water specialists. The values of this factor are displayed in table 3.

Table 3. The yield response factors for cotton and wheat for Uzbekistan.

		Stages	
	Time Period	**Cotton**[a]	**Wheat**[b]
Period 0	10/28 - 11/27	----	0.2
Period 1	11/28 - 4/14	----	0.6
Period 2	4/15 - 5/15	0.2	0.5
Period 3	5/16 - 6/30	0.5	0.4
Period 4	7/1 - 8/30	0.6	----
Period 5	9/1 - 10/27	0.25	----

[a]Farmers seed cotton on April 15 and harvest before October 27.

[b]Farmers seed winter wheat on October 28 and harvest before June 30.

The crop or period with the highest yield response factor suffers the greatest yield loss. Generally, crops are more sensitive to water deficit during emergence, flowering and yield formation than during early and late growth periods. This implies that timing of water supply is as crucial as the level of supply over the total growing period. Table 3 shows that the most sensitive period for cotton is period 4 (mid-season stage) and for wheat is period 1 (crop development stage).

When the irrigation water supply is adequate, fields are generally irrigated to achieve ETa=ETm and reach maximum production Ym. In this practice, called biological optimum irrigation, plants are irrigated whenever needed to prevent moisture stress that would decrease the plant yield. The amount of irrigation water is adjusted to raise the soil moisture content to field capacity. Thus, a yield is at the maximum but not necessary at an economic maximum.

Alternatively, if less irrigation water is available for various reasons and actual NIR is less then required, the actual water consumption of the plant will be lower than its optimum water consumption (ETa< ETm), and the actual yield will be less than the maximum yield. The decrease in yield will vary depending on time, duration and magnitude of the tension created by the deficit water. In this case, irrigation scheduling and crop planning that will ensure highest yield with existing deficit water is important.

If the yield effect is large, it may be better to reduce the cropped area or shift to other crops that can be more adequately irrigated. Otherwise, more conservative irrigation technology may be selected, or deficit irrigation may be carried out. In deficit irrigation, the irrigation water amount is decreased to a certain extent, causing a decrease in yield, but making it possible to irrigate more area with the same amount of water and obtain more income per unit of water.

Responses to the survey, conducted for this study, showed that July-August (denoted as period 4 in this study) is the most critical period and also the most likely period for water shortage. Therefore, most of the focus of this study was devoted to water supply and its reduction in this period.

Farm Cost and Return

The amount of inputs for crop production and their prices were obtained from the survey conducted and cost and returns budgets developed for the Namangan region in summer 2005. The survey was conducted by an international joint project, Partnership for Resources and Environment Management Analysis (PREMA). PREMA is a joint project of Washington State University (WSU), USA and Tashkent Institute of Irrigation and

Melioration (TIIM), Uzbekistan. For this analysis, the survey budgets for cotton and winter wheat were slightly modified according to US Budgeting Standards and are attached in Appendix Tables A1-A10.

Machinery is a major cost for farmers. A majority of the farmers in Namangan region do not have their own machinery for agricultural production because machinery purchase requires a significant amount of initial capital investments. Only a few farmers own some used machinery, acquired during the time of reformation in agriculture. Most surveyed farmers rent machinery from a state-owned Machinery-Tractor Park (MTP). Some farmers prefer to rent from their machinery-owning neighbors because it is usually less expensive. Considering the above mentioned situation with the machinery, the assumption was made that farmers do not have their own machinery in this study and they have to rent it.

Crop selling prices were set at levels reported by the farmers from the survey and from the state marketing agency. Selling price for cotton for the 2004 crop year was 25,200 Uzbekistani soum (UZS)/centner (or $25.20/centner at the typical 2005 exchange rate of 1,000 UZS/US Dollar). The price of wheat sold to the state organization was 8,500 UZS/centner. Wheat sold on the market was valued at 11,000 UZS/centner.

Labor, an important element of crop production in Uzbekistan agriculture, was divided into permanent and seasonal labor. Farmers generally have several permanent workers, often family members, available to provide all types of field operations (plowing, land leveling, harrowing, chiseling, seeding, cultivation, weeding, furrowing, applying fertilizer, etc.). However, farmers also hire outsource (seasonal) workers who are involved only in cotton production (harvesting cotton, weeding and thinning by hand). Permanent labor was divided into two categories: labor for irrigation and other labor.

Labor cost is entered into the objective function through a labor purchasing requirement. All labor used on the crop production activities must be paid a specified wage rate. The base price of labor was assumed to be 120 UZS/hour for permanent labor and 160 UZS/hour for seasonal labor. These rates are based on the response of the farmers from the survey. Alternative permanent labor wage rates are 1 UZS/hour, reflecting a situation of surplus labor with opportunity cost equal zero, and 240 UZS/ hour, reflecting relative labor scarcity.

Alternative Activities

Cotton Activities

Variation in cotton irrigation and yield was made based on: (1) different irrigation techniques as reported from a study that was conducted in Kazakhstan by an Asian Development Bank project; (2) different levels of NIR as calculated by CROPWAT water-yield relationship formula.

The research was conducted in a Kazakhstan region with similar climate condition to the Namangan region in Uzbekistan. Four irrigation techniques were studied to determine their water efficiency and compare productivity and profitability. The irrigation techniques studied were:

1. Traditional furrow irrigation – every furrow on the field is irrigated. Field irrigation efficiency is only 50-56%.
2. Every other furrow irrigation – it can be described as watering every other furrow to reduce water loss. The field irrigation efficiency achieved is 55-65%.
3. Surge irrigation – water flow for irrigating the field starts at a high level, providing fast movement down the furrow. Then water supply to the furrow is stopped for a while before again resuming at a higher rate. This technique decreases technological loss of irrigation water through infiltration and runoff and also reduces the pressure on the drainage system. Farmers irrigate every other furrow by this technique. The field irrigation efficiency varies from 65 to 70%.
4. Discrete irrigation – the water supply is stopped when it reaches 80% length of the furrow. After a pause of about 1-1.5 hours, irrigation is restarted at a lower water flow. The farmer irrigates every other furrow by this technique. The field irrigation efficiency reaches 67-72%.

The alternative irrigation technologies improve field irrigation efficiency but also require more labor. It is also possible to achieve higher efficiency with conventional furrow irrigation by closer monitoring and improving precision in irrigation, improving uniformity within the field, timing irrigation more closely to crop water requirements and soil moisture level, more frequent irrigation, and dividing fields into shorter lengths of run. But this study considered only improving irrigation efficiency by applying more efficient furrow irrigation techniques that display labor-water substitution to maintain a higher yield when reduced water supply decrease.

Studies conducted in Uzbekistan and neighboring countries also indicate that improvement in irrigation efficiency leads to higher cotton yield. A study conducted in the southern part of Kazakhstan showed that applying cutback alternate furrow irrigation reduces surface losses by 10% and evapotranspiration by 12%. Meanwhile, by using these improved irrigation techniques, farmers gained 14 % higher yield compared to traditional furrow irrigation (Karimov, 2005). In addition, Kamilov et al. in their research about precise scheduling of drip irrigated cotton showed an increase in cotton yield accompanied by improvement in water use efficiency even compared to relatively well managed surface irrigation (Kamilov et al., 2002).

The budgets developed under PREMA project were slightly modified for using these four irrigation techniques under the conditions of Namangan region. Table 4 shows the cost and returns for each of these irrigation techniques. These four budgets are denoted as four basic cotton irrigation activities for the model of this paper. The more detailed cotton budgets are presented in the appendix for each irrigation technique (table A1-A8).

Other cotton activities were developed based on reduced water supply in period 4, the most critical one for cotton. It was assumed that farmers do not take any actions to better irrigate their field under water deficit conditions, a reduction in water supply is reflected in reduced NIR. It was decided to use 90%, 80%, 70% and 60% of NIR availability (water supply) to the crop. The resulting decrease in yield was calculated by a water-yield relationship formula:

$$Y_a / Y_m = 1 - K_y * (1 - ET_a / ET_m)$$

Table 4. Comparison of four irrigation techniques for cotton production, 2005.

Items	Unit	Conventional Furrow	Alternative Techniques[a]		
			Initial	Surge Flow	Discrete Flow
Variable Cost					
Fertilizers	UZS	108 650	108 650	108 650	108 650
Pest Control	UZS	3 000	3 000	3 000	3 000
Renting Machinery	UZS	92 500	92 500	92 500	92 500
Machinery Fuel / Lube	UZS	27 115	27 115	27 115	27 115
Permanent Labor, including:	UZS	48 246	54 966	57 666	63 126
Labor for Irrigation	UZS	*18 720*	*19 440*	*22 140*	*27 600*
Seasonal Labor	UZS	40 800	44 880	44 880	44 880
Overhead	UZS	16 016	16 556	16 691	16 964
Total Variable Cost	UZS	336 327	347 667	350 502	356 235
Fixed Cost					
Land Tax	UZS	9 059	9 059	9 059	9 059
WUA Fee	UZS	9 000	9 000	9 000	9 000
Total Fixed Cost	UZS	18 059	18 059	18 059	18 059
TOTAL COST	UZS	354 386	365 726	368 561	374 294
Gross & Net Returns					
Yield	centner/ha	23.2	25.78	25.78	25.78
Gross Return	UZS/ha	584 640	649 656	649 656	649 656
Farm Income	UZS/ha	230 254	283 930	281 095	275 362
Labor					
Total irrigation labor use	hr/ha	156	202	225	265
Other permanent labor	hr/ha	247	256	256	256
Seasonal labor	hr/ha	255	280	280	280
Total labor:	hr/ha	658	738	761	801
Change in irrigation labor	hr/ha		46	69	109
Water					
Field Irrigation Efficiency	%	53%	60%	68%	70%
Water use (m3/ha)	m3/ha	11 768	10 395	9 173	8 910
Water saved	m3/ha		1 373	2 595	2 858
Income /water	UZS/m3	19.6	27.3	30.6	30.9

[a]Alternative techniques irrigate every other furrow.

Cost calculations are based on the traditional furrow irrigation activity for cotton. Labor stays the same as for traditional furrow irrigation, because of the assumption that farmers took no actions to improve field irrigation when NIR decreases. However, there is a reduction in permanent labor (excluding labor for irrigation) and in seasonal labor, because of the reduction in yield.

Wheat activities

Wheat activity variation for water use is based on the study titled "Economic study of the potential for water markets in Idaho" by Whittlesey and Hamilton (1986). Alternative ways of irrigating crops in southern Idaho, including winter wheat, were simulated to reflect the tradeoff that can occur when water supplies are reduced. Whittlesey and Hamilton used the crop growth simulation program CROPSYS to calculate yield, NIR and field irrigation efficiency under alternative ways of irrigating crops and reduced levels of actual NIR. A logarithmic regression of the relationship among these outcomes was estimated as:

$$\text{Log(Yield)} = \underset{(3.5715)}{3.0136} + \underset{(-2.5401)}{0.3543\ \text{Log(NIR)}} - \underset{(4.4178)}{0.3399\ \text{Log(Irr. Eff-cy)}} + \underset{(5.4710)}{0.30695\ \text{Log(Labor)}}$$

$$R^2 = 0.9367$$

which was converted into Cobb-Douglas form:

$$\text{Yield} = 20.3\ \text{NIR}^{0.3543}\text{Irr.Eff-cy}^{-0.33994}\text{Labor}^{0.30695}$$

In general this form captures the principle that, as water becomes more limiting, it is practical for the irrigator to use more labor to apply more frequent, smaller applications of water to raise the irrigation efficiency and consequently yield from a given quantity of water.

An example of the alternative irrigation activities for winter wheat is shown in table A12 in the Appendix. In the left margin of this table is shown an index of the net irrigation requirement and the cubic meters of consumptive water use that would be used to irrigate wheat at each level of water use. For each level of water consumptive use, several alternative levels of irrigation efficiency may be used. The same levels of irrigation efficiency as for cotton were used (53, 60, 68 and 70%). Subsequent columns in this table then show the estimated amount of applied water, a yield index and the estimated yield in centners per hectare for alternative levels of efficiency in irrigating this crop. Also calculated and shown for each of the irrigation activities is an estimate of labor use and the total variable costs of production, adjusted to account for costs that are proportionate to yield.

In the response to a change in the quantity of delivered water, the farmer may change the level of irrigation efficiency, the consumptive use of water for cotton or wheat or the hectares of crops that are produced. As the irrigation efficiency and water application for these crops is changed, the labor requirements will also change. The optimum response for a farmer to any given level of water supply will depend upon the price of labor, the prevailing irrigation technology, and the value of the crops that are produced. The responses derived in this analysis are based upon the assumed costs of production, yields and crops which were shown in the previous table.

The budget of the base wheat activity is presented in Appendix, table A9-A10. The field irrigation efficiency for the base case is assumed to be 53%. The crop water requirements (NIR) for wheat were calculated with the help of CROPWAT program. The yield and labor requirements with different levels of efficiency and actual NIR are based on coefficients obtained from regression mentioned above.

Optimization Model and Scenarios

The objective function of the optimization model maximizes net farm income as the sum of cotton and wheat sales minus variable costs of production while concurrently accounting for constraints of key resources such as land area, water use and labor.

Mathematically, the objective function can be written as:

$$\max Z = \sum_{i}^{n} \mathrm{A_i}\ \mathrm{GM_i}$$

Where:

A_i : planted area of crop *i*, in hectares

GM_i : gross margin for crop *i* calculate as the difference between market sales and variable costs:

$$\mathrm{GM_i} = (\mathrm{Y_i} * \mathrm{P_i}) - \mathrm{VC_{ij}} - (\mathrm{L_{ij}} * \mathrm{LP_j})$$

Where:

Y_i : the yield from *i* crop

P_i : price of *i* crop

VC_{ij} : the variable costs *j* (such as machinery, fertilizer, seeds and others but excluding labor) required to produce crop *i*

L_{ji} : amount of labor *j* required to produce crop *i*

LP_j : prices of labor (permanent and seasonal).

QM for Windows software was utilized for solving the linear programming models.

Five scenarios were simulated with the LP model, using different combinations of cropping patterns which are summarized below:

Scenario 1 – Base case. Cotton and wheat production occurs only with the conventional furrow irrigation (53% efficiency). Farmers are required to grow at least 8 ha. but not more than 10 ha. of cotton. The area for wheat is required to be at least 6 ha. The prices of permanent and seasonal labor are 120 UZS/hr. and 160 UZS/hr., respectively. The amounts of water supplied to the fields are sufficient for 10 ha. of cotton and 10 ha. of wheat.

Scenario 2 – Reduction in water supply in period 4 is introduced. The rest of the settings are the same as in Scenario 1.

Scenario 3 – Introduction of alternative irrigation techniques with higher levels of irrigation efficiency (60, 68 and 70%). Reduction in water supply in period 4 is analyzed in this scenario.

Scenario 4 – Doubling the price of permanent and seasonal labor. The rest of the settings are the same as in scenario 3.

Scenario 5 – Reduction in the price of permanent labor down to 1 UZS/hr. The rest of the settings are the same as in scenario 3.

Results

Scenario 1. Base Case

The first run of the model, denoted as Scenario 1 or the base case, represents typical activities and conditions for wheat and cotton production on a typical farm in the Namangan region. The irrigation is conventional furrow with field irrigation efficiency of 53%. More efficient irrigation technology is not available in the base case. July-August is the critical time of water need and also of shortage for farmers; however, for the base case, it was assumed that farmers receive 100% of water required in all periods.

The farm consists of 20 hectares of irrigated cropland and grows cotton and wheat as required by the state order. Labor is assumed to be available as needed for the conventional wage rates of 120 UZS/hour for permanent labor and 160 UZS/hour for seasonal workers.

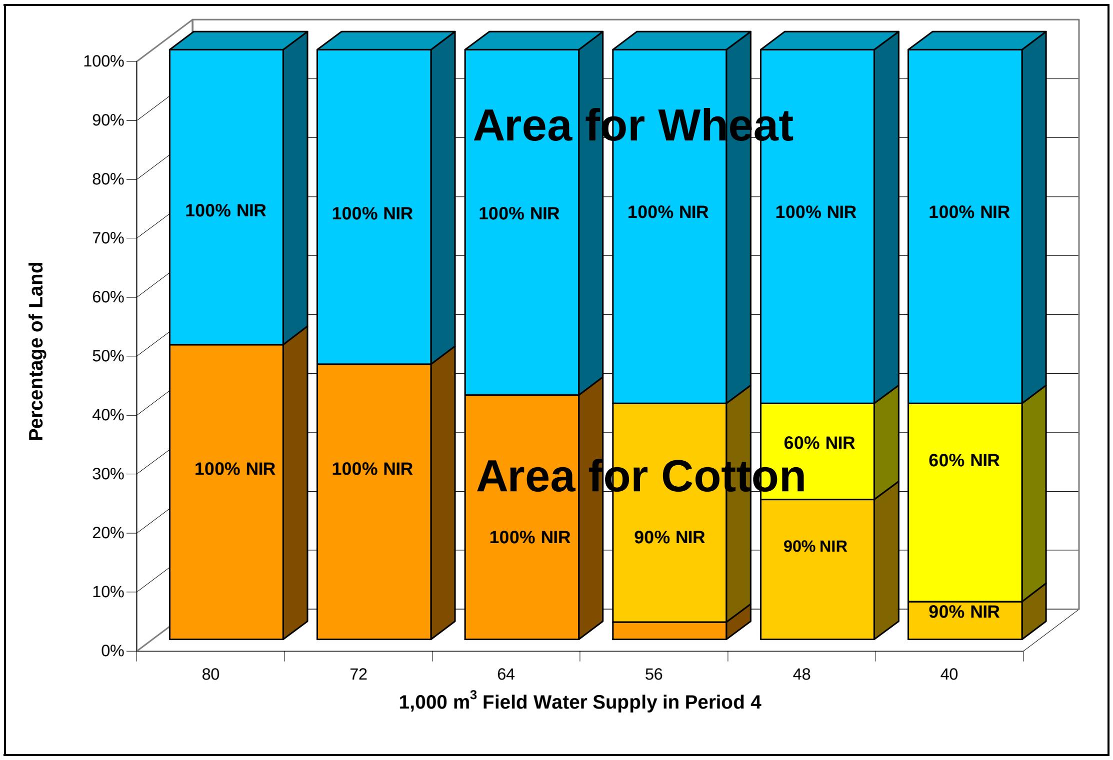
The profit maximizing results of the model showed that, when water is sufficient, farmers would grow the maximum permitted 10 ha. of cotton and, on the rest of their land, 10 ha. of wheat. There was no water related reduction in area harvested or yield, leading to a total harvest of 232 centner of cotton and 349 centner of wheat. The net return above variable costs from cotton and wheat production is 2,985,000 UZS (or about $2,985 USD). The farmer has certain fixed costs (land taxes and WUA fee), leaving about 2,624,000 UZS as net farm income. Total income from the farm, including wages received by farm workers, was estimated to be 3,681,000 UZS.

It is important to mention that without any land constraints, the model would show it optimal to plant cotton on the whole 20 ha. because it is more profitable than wheat. Shadow prices, also referred to as dual prices in the linear programming solution, indicate how much farm income would increase if a constraint were relaxed by one unit. The shadow (dual) price can be explained as a marginal value. The marginal value of planting another hectare of cotton is 198,000 UZS. This marginal value indicates that net farm return would increase by this amount, if the upper bound of the land constraint for cotton would be relaxed by 1 hectare.

Scenario 2. Reduced water supply

For Scenario 2, a decrease in water supply in period 4 affects crop pattern and net return. Figure 2 & table 5 represent the results of the runs when the farmer receives a reduced supply of water available for irrigation in period 4. Reduction of water supply in period 4 by only 10% makes it more profitable to slightly increase the area for growing wheat and decrease the area for cotton. Net return declines by 4% and total income to farmer and farm workers declines by 5%.

Figure 2. Area planted to cotton and wheat at optimum with decreasing levels of water supply in period 4 – Conventional irrigation case[a].



[a]Field Irrigaiton Efficiency is 53%.
[b]NIR = Net Irrigation Requirement

A further decrease to 70% availability of water in period 4 leads to a decrease in area of growing cotton to the minimum permitted 8 ha and increase to 12 ha of wheat, which requires no water in period 4 and thus unaffected. Most of the cotton growing will receive only 90% of NIR and consequently produce a lower yield. Farm net return is down by more then 20% and the marginal value (increased net income gained) from 1 m^3 of water in period 4 at that time would be 40 UZS. At 60% or less of water supply, marginal value is 42 UZS/m^3.

If water in period 4 is reduced by 40% or more in the base case, the same land allocation (8 ha of cotton and 12 ha of wheat) is continued to satisfy the order limits. However, NIR supply for cotton will have to be reduced. At 50% of base water use, 4.74 ha of cotton will receive 90% NIR and 3.26 ha of cotton will receive only 60%. The net return in this case is 2,030,000 UZS, about 30% lower then in the base case. With only one-half as much water, area planted still must be 8, but most will receive only 60% NIR. Net return from cotton and wheat production is 1,698,000 UZS.

At this point it is costly to continue to plant 8 ha. to cotton when water supply is so reduced. Reducing the order by just 1 ha. would save 121,000 UZS in net income. Without any cotton area requirement the optimal would be 5.1 ha. of cotton and 14.82 ha. of wheat and income would be higher by 332,000 UZS.

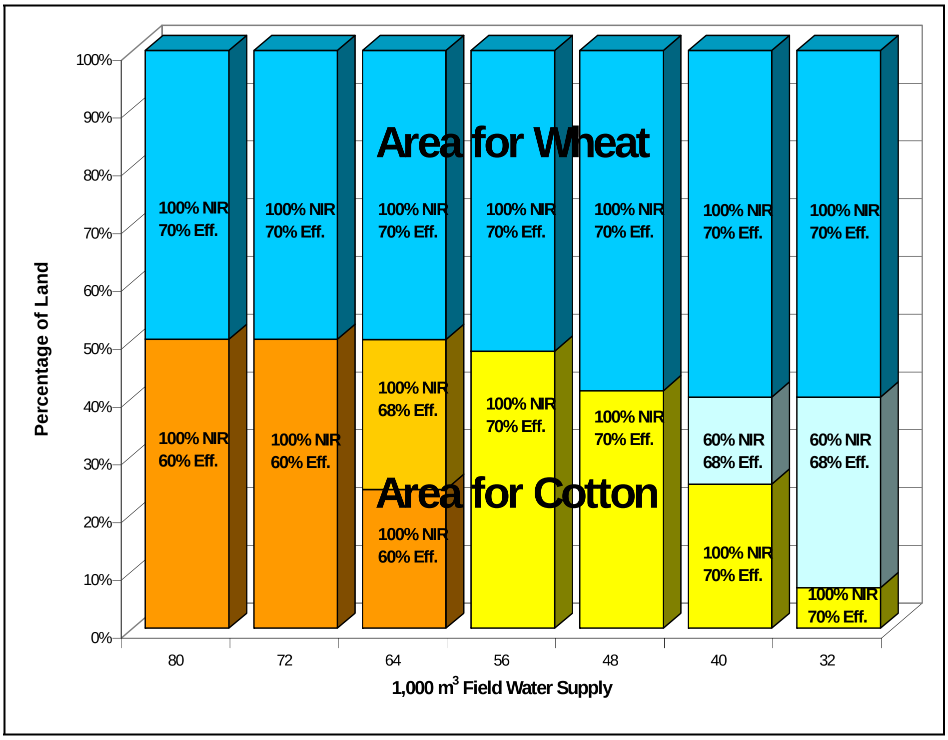
Table 5. Net income and values at optimum with decreasing levels of water supply in period 4 – Base case.

	Unit	Water Supply in Period 4					
		80 000	**72 000**	**64 000**	**56 000**	**48 000**	**40 000**
		100%	**90%**	**80%**	**70%**	**60%**	**50%**
Gross Return:							
Cotton	1,000 UZS	5 846	5 455	4 849	4 417	4 053	3 689
Wheat	1,000 UZS	3 216	3 431	3 765	3 859	3 859	3 859
Labor:							
Total irrigation labor use	hrs	2 360	2 309	2 230	2 208	2 208	2 208
Other permanent labor	hrs	3 048	2 922	2 727	2 627	2 630	2 637
Seasonal labor	hrs	2 550	2 379	2 115	1 917	1 750	1 582
Net Return & Wages:							
Net Return over VC:	1,000 UZS	2 985	2 852	2 647	2 362	2 030	1 698
Land tax & WUA fee	1,000 UZS	361	361	361	361	361	361
Net Farm Income	1,000 UZS	2 624	2 491	2 28 6	2 001	1 669	1 336
Permanent labor wages paid	1,000 UZS	649	628	595	580	581	581
Seasonal labor wages paid	1,000 UZS	408	381	338	307	280	253
Total income to farmer & labor	1,000 UZS	3 681	3 499	3 219	2 888	2 530	2 171
Water Use:							
Total water use	1,000 m^3	205	200	192	184	176	168
Gross return / water used total	UZS/m^3	44	44	45	45	45	45
Gross return / water used in period 4	UZS/m^3	117	123	135	148	165	189
Net Return / water used total	UZS/m^3	13	12	12	11	9	8
Net Return / water used in period 4	UZS/m^3	34	35	36	36	35	33
Net returns & wages / water used total	UZS/m^3	18	17	17	16	14	13
Net returns & wages / water used in period 4	UZS/m^3	48	49	50	52	53	54
Marginal Values							
Water in period 4	UZS/m^3	0	26	25.68	39.56	41.57	41.57
Cotton acreage - Upper bound	UZS/ha	198 148	0	0	0	0	0
Cotton acreage - Lower bound	UZS/ha	0	0	0	-107 075	-121065	-121 065

Scenario 3. Alternative Irrigation Techniques

Introducing alternative water saving irrigation techniques in the model results in a slightly different allocation of land and water. Figure 3 and table 6 reports the cropping pattern, NIR and irrigation efficiency. With sufficient water supply in period 4, profit will be maximized by producing 10 ha of cotton and 10 ha of wheat. Net farm income in this case is 3,244 thousand UZS.

Figure 3. Area planted to cotton and wheat at optimum with decreasing levels of water supply in period 4 – Conventional and alternative irrigation techniques.



[a]NIR = Net Irrigation Requirement

It is important to emphasize that farmers will benefit by shifting to more efficient irrigation techniques even if water is sufficient. When improved irrigation methods are a feasible alternative, the area and cropping pattern is the same as in the base case

(Scenario 1). But production and income are higher, and considerably higher in a very short water situation.

If an increase in yield does not occur by using an alternative irrigation technique when water supply is sufficient, farmer would still grow 10 ha of cotton and 10 ha of wheat using traditional irrigation techniques. Net income will be 2,707 thousands UZS. However, a reduction in water supply in period 4 by 50% will make it profitable for farmers to use alternative irrigation techniques with higher efficiency, even though they promise no increase in yield. Maximum net returns can come from planting 4.98 ha and 3.02 ha of cotton using 70% and 68% efficiency techniques and 12 ha of wheat in order to meet cotton and wheat land requirements operate within the limited water availability. Net income will drop to 1,801 thousand UZS in this case, which is still 35% above what could have been gained with conventional inefficient irrigation and the same limited water supply.

Table 7 show the detailed comparison of optimum values and net income for the conventional only versus alternative irrigation techniques cases with 100% and 50% of water supply in period 4. At 100% water supply, availability of alternative techniques leads to consuming less water (32,000 m^3 less). Marginal value of the upper bound of cotton acreages raises by 45,000 UZS. If water is sufficient, farmers profit by planting even more than the government order requires because cotton is much more profitable than wheat. They are held back by the 10 ha upper bound, imposed for agronomic and whole farm management reason.

There are several advantages, other then saving water, for the alternative, more water efficient, technologies.

1. Better yield, 11% higher for cotton according to ADB research report on irrigation techniques used in this study. Greater precision in water application not only saves water but also improves uniformity and reduces over- and under-irrigation of parts of the field. Other reports also attest to potential for greater yield from use of the water conserving technology.
2. More "productive" work for unemployed rural farm workers – Total labor use increases by 14% for optimal with alternative versus conventional only irrigation techniques when full water supply is available. The base case requires 7,958 labor hours and the improved efficiency case increases to 9,048 labor hours that is 14% higher. With only 50% of period 4 water, the employment gain is 27%. The increase involves more work in irrigation and in harvesting the higher yield.
3. Higher incomes:
    a) Gross income - 770,000 UZS or 8% increase from the base case due to the higher yields.
    b) Net farm income – 620,000 UZS indicating 24% increase from the base case. Many costs are the same per hectare; income increases much more then costs. (But we may have underestimated some increases in non-labor costs such as more fertilizer to support higher yields or more machinery costs for leveling and field preparation).
    c) Increased total earning of farmer and local workers – 761,000 UZS higher for alternative techniques, a 21% increase.
4. Higher return per m^3 of water.13 versus 19 UZS/m^3.
5. Much less decline in income form serious drop in water supply in the most critical period (period 4).

Table 6. Optimum values and farm income with decreasing levels of water supply in period 4 – With alternative irrigation techniques

		Water Supply in Period 4						
		80 000	**72 000**	**64 000**	**56 000**	**48 000**	**40 000**	**32 000**
	Unit	**100%**	**90%**	**80%**	**70%**	**60%**	**50%**	**40%**
Gross Return:								
Cotton	1,000 UZS	6 497	6 497	6 497	6 230	5 338	4 727	4 168
Wheat	1,000 UZS	3 335	3 335	3 335	3 473	3 930	4 002	4 002
Labor:								
Total irrigation labor use	hrs	3 100	3 100	3 217	3 713	3 491	3 319	3 156
Other permanent labor	hrs	3 143	3 143	3 143	3 061	2 790	2 730	2 708
Seasonal labor	hrs	2 805	2 805	2 805	2 689	2 305	2 040	1 799
Net Return & Wages:								
Net Return over VC:	1,000 UZS	3 605	3 605	3 590	3 422	3 100	2 636	2 145
Land tax & WUA fee	1,000 UZS	361	361	361	361	361	361	361
Net Farm Income	1,000 UZS	3 244	3 244	3 229	3 061	2 739	2 275	1 784
Permanent labor wages paid	1,000 UZS	749	749	763	813	754	726	704
Seasonal labor wages paid	1,000 UZS	449	449	449	430	369	326	288
Total income to farmer & labor	1,000 UZS	4 442	4 442	4 441	4 304	3 862	3 327	2 776
Water Use:								
Total water use	1,000 m^3	173	173	166	153	145	138	130
Gross return / water used total	UZS/m^3	57	57	59	63	64	63	63
Gross return / water used in period 4	UZS/m^3	144	144	154	173	193	218	255
Net Return / water used total	UZS/m^3	19	19	19	20	19	17	14
Net Return / water used in period 4	UZS/m^3	48	48	50	55	57	57	56
Net returns & wages / water used total	UZS/m^3	26	26	27	28	27	24	21
Net returns & wages / water used in period 4	UZS/m^3	65	65	69	56	80	83	87
Marginal Values								
Water in period 4	UZS/m^3	0	0	3.53	40.21	40.21	61.37	61.37
Cotton acreage -Upper bound	UZS/ha	243 470	243 470	219 376	0	0	0	0
Cotton acreage - Lower bound	UZS/ha	0	0	0	0	0	-123 646	-123 643

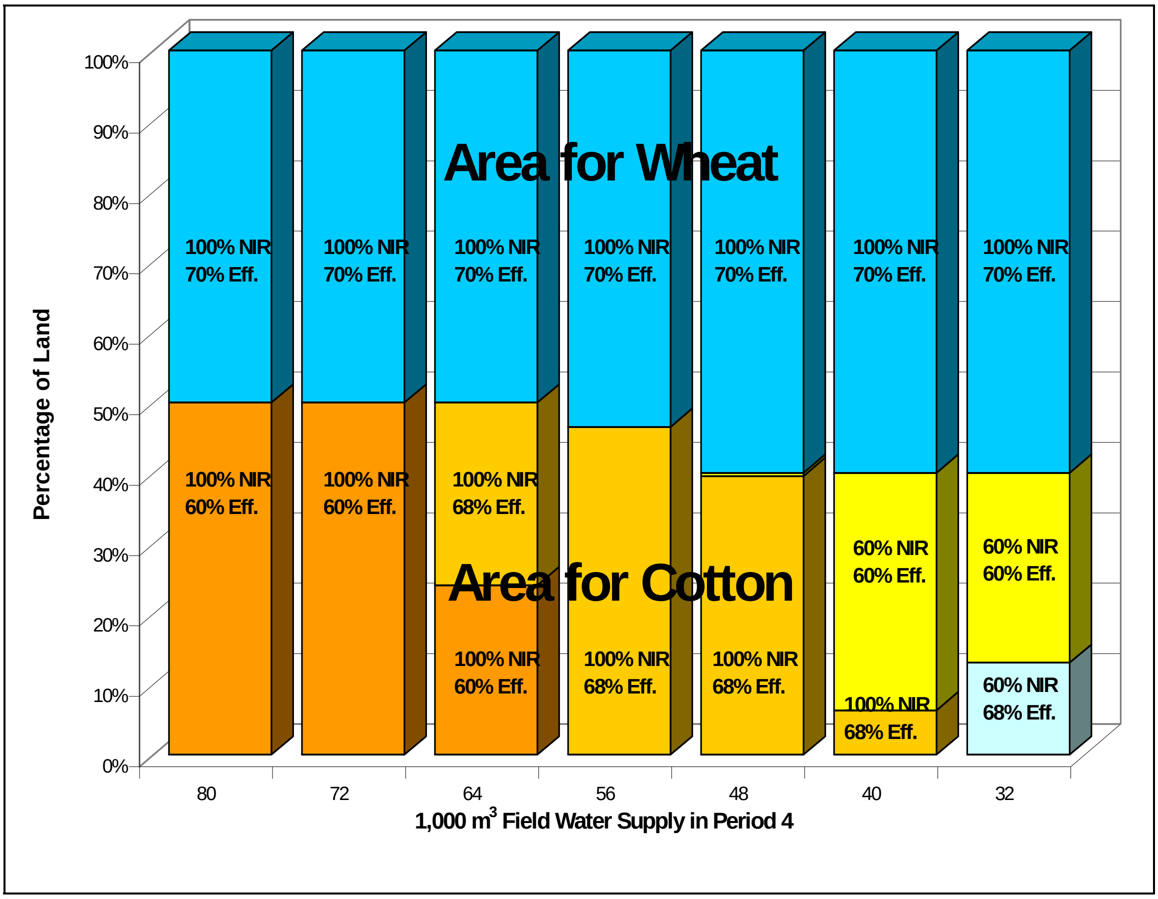
Table 7. Comparison of optimum values and net income with 100% and 50% of water supply in period 4 – Conventional only and alternative irrigation techniques cases.

	Unit	100% Water Supply in Period 4			50% Water Supply in Period 4		
		Base Case	Alternative Irrigation Techniqes	Difference	Base Case	Alternative Irrigation Techniqes	Difference
Gross Return:							
Cotton	1,000 UZS	5 846	6 497	650	3 689	4 727	1 038
Wheat	1,000 UZS	3 216	3 335	119	3 859	4 002	143
Labor:							
Total irrigation labor use	hrs	2 360	3 100	740	2 208	3 319	1 111
Other permanent labor	hrs	3 048	3 143	95	2 637	2 730	93
Seasonal labor	hrs	2 550	2 805	255	1 582	2 040	458
Net Return & Wages:							
Net Return over VC:	1,000 UZS	2 985	3 605	620	1 698	2 636	939
Land tax & WUA fee	1,000 UZS	361	361	0	361	361	0
Net Farm Income	1,000 UZS	2 624	3 244	620	1 336	2 275	939
Permanent labor wages paid	1,000 UZS	649	749	100	581	726	144
Seasonal labor wages paid	1,000 UZS	408	449	41	253	326	73
Total income to farmer & labor	1,000 UZS	3 681	4 442	761	2 171	3 327	1 156
Water Use:				0			
Total water use	1,000 m^3	205	173	-32	168	137	-31
Gross return / water used total	UZS/m^3	44	57	13	45	63	18
Gross return / water used in period 4	UZS/m^3	117	127	10	189	218	29
Net Return / water used total	UZS/m^3	13	19	6	8	17	9
Net Return / water used in period 4	UZS/m^3	34	42	8	33	57	24
Net returns & wages / water used total	UZS/m^3	18	26	8	13	24	11
Net returns & wages / water used in period 4	UZS/m^3	48	58	10	54	83	29
Marginal Values							
Water in period 4	UZS/m^3	0	0	0	41.57	61.37	20
Cotton acreage - Upper bound	UZS/ha	198 148	243 470	45 322	0	0	0
Cotton acreage - Lower bound	UZS/ha	0	0	0	-121 065	-123 646	-2 581

Scenario 4 and 5. Changing Labor Prices

Figure 4 displays the optimum cropping pattern of Scenario 4 as water supply in period 4 varies when permanent and seasonal labor prices are doubled. It shows that higher labor prices do not make a big difference on cropping pattern. However, it does discourage use of the more efficient but labor demanding irrigation technologies and thus leads to more reduction in NIR and less gain in efficiency when water supply in period 4 is reduced by 50% or more.

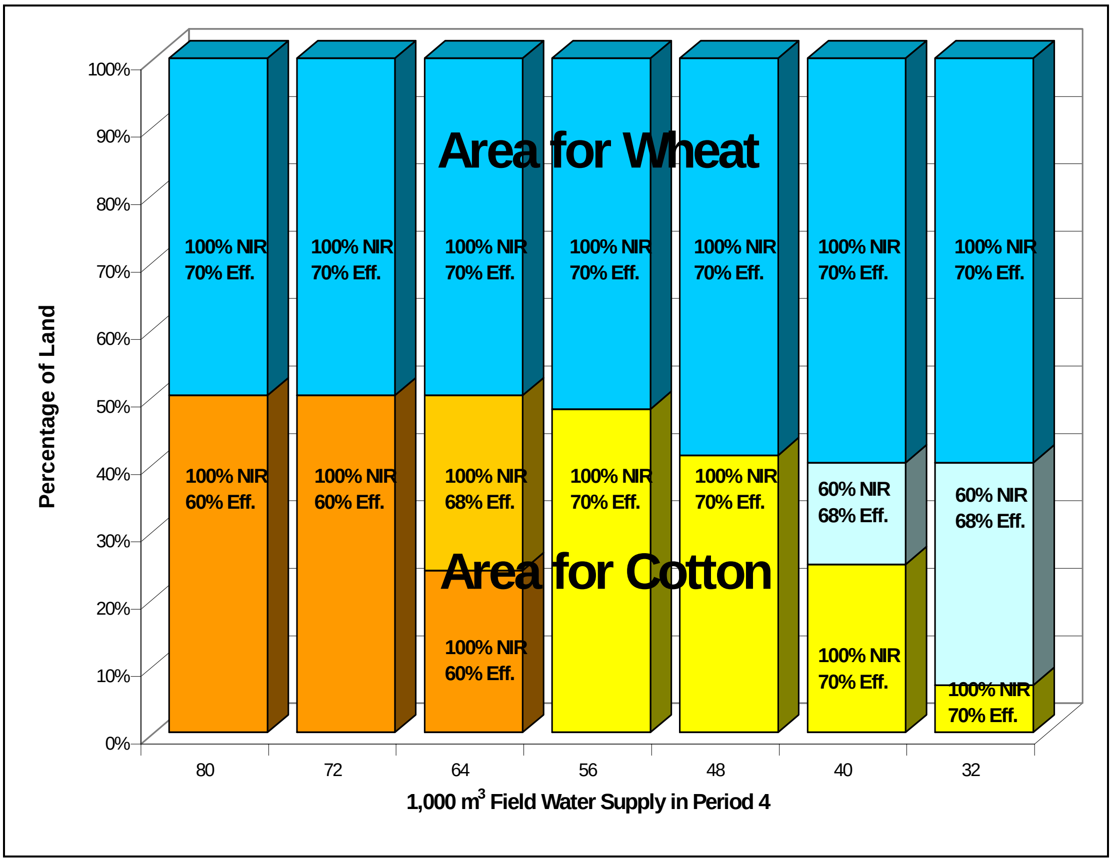
Figure 4. Area planted to cotton and wheat at optimum with decreasing levels of water supply in period 4 and increase in prices of labor – Conventional and alternative irrigation techniques.



[a]NIR = Net Irrigation Requirement

Figure 5 displays the cropping pattern of cotton and wheat at the optimum for Scenario 5 when permanent labor price is only 1 UZS/hr, virtually zero, and seasonal labor is 160 UZS/hr. As water supply varies in period 4, land allocation is almost the same as when labor prices were much higher. The only thing changed is an increase in irrigation efficiency when water supply in period 4 is reduced. Farmers use more permanent labor that almost does not contribute to an increase in production costs, in order to make better use of scarce water and achieve higher yield.

Figure 5. Area planted to cotton and wheat at optimum with decreasing levels of water supply in period 4, permanent labor price is 1 UZS/hr and seasonal labor price is 160 UZS/hr – Conventional and alternative irrigation techniques.



[a]NIR = Net Irrigation Requirement

In summary, a wide range of labor prices has no effect on farming program when there is a full water supply in period 4. When farmers receive 50% or less water in period 4, there is an insignificant change in amount of labor and net income. It might be explained by the fact that minimum constraint of cotton planting and the high income from cotton make the solution inflexible. However, increases in labor prices do delay the switch to more efficient irrigation techniques resulting into lower yield and net income.

Conclusion

The study shows that farmers can expect to earn higher incomes when they grow more cotton even without any government determination of what to grow. Cotton is simply much more profitable compared to wheat. The results of the model shows that adopting improved irrigation methods improving field irrigation efficiency would allow farmers to not only minimize the effect of water shortage but also to achieve higher yield and consequently higher net farm returns for both of these crops. Water use efficiency can be increased by applying alternative furrow irrigation techniques or by more intensive management using conventional techniques. Either generally requires more labor for more precise and careful management of water during short periods. It also was observed that increasing the price of labor does not change the relative profitability of alternative techniques.

Improved irrigation produces higher income, especially when water supply is short, but also even with adequate water supply. The results of this study indicate that it is probably not necessary for the government to require to plant a certain area in cotton. According to the costs and returns used here, expanded cotton production above constrained levels would be profitable. Relaxing constraints on area planted to cotton will lead to an increase in production and in farm income under both adequate and moderately deficit water supply conditions. However, severe water shortage in the critical late summer period would create a situation in which the farmer's expected income would be increased if cotton area planted could be reduced and replaced with wheat which requires water in the fall, winter and spring.

This study also indicates that water becomes more valuable when farmer receive 50% or less of the normal water supply in the most critical period. The high shadow price for water in this period reflects that, when there is a water shortage in the critical late summer period, farmers could increase incomes even while paying much more then current fees for water if doing so would give them a greater supply in the critical time.

The water management agency should encourage farmers to adopt higher efficiency irrigation technology. This will increase crop yields and save water. Extension services may explain gains to farmers; introduce monetary incentives for saving water, and price water at market levels to promote adoption of more efficient irrigation technology.

Future research should examine introduction of more advanced irrigation technologies with up front capital investments such as lining distribution canals and ditches, consideration of drip and gated pipe systems, introduction of forage and livestock production into farm plans, and comparing profitability and water use efficiency of cotton and wheat production to the vegetable and fruit production on the *dekhkan* plots.

Appendix

Table A1. Itemized Cost Per Hectare for Cotton, Traditional Furrow Irrigation, Namangan Region, Uzbekistan, 2005.

	Unit	Price or Cost / Unit	Quantity	Value or Cost
Variable Costs				
Suppephoshate	kg	65	300	19 500
Seeds	kg	225	60	13 500
Nitrogen	kg	123	550	67 650
Organic Manure	kg	2	4000	8 000
Pest Control (biological) - Oltinkuz, Trichogramma	ha	3 000	1	3 000
Renting Machinery	ha	92 500	1	92 500
Machinery Fuel/Lube	ha	27 115	1	27 115
Permanent Labor	hour	120	402	48 246
Seosonal Labor	hour	160	255	40 800
Overhead	ha	16 016	1	16 016
Total Variable Cost				**336 327**
Fixed Costs				
Land Taxes	ha	9 059	1	9 059
WUA Fee	ha	9 000	1	9 000
Total Fixed Cost				**18 059**
TOTAL COST				**354 386**

Cotton yield is assumed to be 23.2 centners/ha.

Cotton price is 25,200 UZS/centner.

Table A2. Schedule of Operations and Estimated Costs Per Hectare for Cotton, Traditional Furrow Irrigation, Namangan Region, Uzbekistan, 2005.

#	Operation	Tooling	Month	Mach Hour	Permanent Labor Hour	Seasonal Labor Hour	Variable Cost				Total Variable Costs	Total Fixed Costs	Total Costs
							Fuel, Lube & Repair	Mach Labor	Service	Material			
1	Plow	Magnum Tractor	Nov	1.25	4.00	0.00	5 075	480	19 000	19 500	44 055	0	44 055
2	Land Level	Magnum Tractor	Apr	0.75	1.65	0.00	3 480	198	8 000	0	11 678	0	11 678
3	Harrow	Magnum Tractor	Apr	0.88	2.80	0.00	4 060	336	8 000	0	12 396	0	12 396
4	Furrow One	T-28 Tractor	Apr	0.75	1.65	0.00	1 160	198	5 000	0	6 358	0	6 358
5	Seed	T-28 Tractor	Apr	1.25	4.00	0.00	1 450	480	5 000	13 500	20 430	0	20 430
6	Irrigate One	By hand	April	0.00	48.00	0.00	0	5 760	0	0	5 760	0	5 760
7	Cultivate One	T-28 Tractor	May	1.50	4.80	0.00	1 450	576	5 500	0	7 526	0	7 526
8	Thin	By hand	May	0.00	20.00	25.00	0	6 400	0	0	6 400	0	6 400
9	Furrow Two & Fertilize	T-28 Tractor	May	1.25	4.00	0.00	1 160	480	5 000	30 750	37 390	0	37 390
10	Weed One	By hand	June	0.00	24.00	30.00	0	7 680	0	0	7 680	0	7 680
11	Cultivate Two	T-28 Tractor	June	1.25	2.75	0.00	1 160	330	5 000	0	6 490	0	6 490
12	Irrigate Two & Fertilize	By hand	June	0.00	42.00	0.00	0	5 040	0	8 000	13 040	0	13 040
13	Furrow Three & Fertilize	T-28 Tractor	July	1.00	3.20	0.00	1 160	384	5 000	36 900	43 444	0	43 444
14	Cultivate Three	T-28 Tractor	July	1.00	2.20	0.00	1 160	264	5 000	0	6 424	0	6 424
15	Cultivate Four	T-28 Tractor	July	1.00	2.20	0.00	1 160	264	5 000	0	6 424	0	6 424
16	Irrigate Three	By hand	July	0.00	36.00	0.00	0	4 320	0	0	4 320	0	4 320
17	Pest Control (biological)	By hand	July	0.00	2.50	0.00	0	300	0	3 000	3 300	0	3300
18	Weed Two	By hand	Aug	0.00	16.00	0.00	0	1 920	0	0	1 920	0	1 920
19	Furrow Four	T-28 Tractor	Aug	0.75	1.65	0.00	1 160	198	5 000	0	6 358	0	6 358
20	Cultivate Five	T-28 Tractor	Aug	0.75	1.65	0.00	1 160	198	5 000	0	6 358	0	6 358
21	Irrigate Four	By hand	Aug	0.00	30.00	0.00	0	3 600	0	0	3 600	0	3600
22	Cut top of cotton plant	By hand	Aug	0.00	40.00	0.00	0	4 800	0	0	4 800	0	4800
23	Harvest One	By hand	Sep	0.00	65.00	162.50	0	33 800	0	0	33 800	0	33800
24	Harvest Two	By hand	Sep	0.00	30.00	37.50	0	9 600	0	0	9 600	0	9600
25	Transport One	T-28 Tractor	Sep	3.00	9.60	0.00	1 160	1 152	6 000	0	8 312	0	8312
26	Transport Two	T-28 Tractor	Oct	0.75	2.40	0.00	1 160	288	1 000	0	2 448	0	2448
27	Land Taxes	Land Taxes	Ann.	0.00	0.00	0.00	0	0	0	0	0	9 059	9 059
28	WUA Fee	Deliver Water Fee	Ann.	0.00	0.00	0.00	0	0	0	0	0	9 000	9 000
29	Overhead	Utiities, Acct., Legal, Etc.	Ann.	0.00	0.00	0.00	0	0	16 016	0	16 016	0	16 016
	TOTAL:			**17.13**	**402.05**	**255.00**	**27 115**	**89 046**	**108 516**	**111 650**	**336 327**	**18 059**	**354 386**

Table A3. Itemized Cost Per Hectare for Cotton, Every Other Furrow (Initial) Irrigation, Namangan Region, Uzbekistan, 2005.

	Unit	Price or Cost / Unit	Quantity	Value or Cost
Variable Costs				
Superphosphate	kg	65	300	19 500
Seeds	kg	225	60	13 500
Nitrogen	kg	123	550	67 650
Organic Manure	kg	2	4000	8 000
Pest Control (biological) - Oltinkuz, Trichogramma	ha	3 000	1	3 000
Renting Machinery	ha	92 500	1	92 500
Machinery Fuel/Lube	ha	27 115	1	27 115
Permanent Labor	hour	120	458	54 966
Seasonal Labor	hour	160	280	44 880
Overhead	ha	16 556	1	16 556
Total Variable Cost				**347 667**
Fixed Costs				
Land Taxes	ha	9 059	1	9 059
WUA Fee	ha	9 000	1	9 000
Total Fixed Cost				**18 059**
TOTAL COST				**365 726**

Cotton yield is assumed to be 25.78 centners/ha.

Cotton price is 25,200 UZS/centner.

Table A4. Schedule of Operations and Estimated Costs Per Hectare, Cotton, Every Other Furrow (Initial) Irrigation, Namangan Region.

#	Operation	Tooling	Month	Mach Hour	Permanent Labor Hour	Seasonal Labor Hour	Variable Cost				Total Variable Costs	Total Fixed Costs	Total Costs
							Fuel, Lube & Repair	Mach Labor	Service	Material			
1	Plow	Magnum Tractor	Nov	1.25	4.00	0.00	5 075	480	19 000	19 500	44 055	0	44 055
2	Land Level	Magnum Tractor	Apr	0.75	1.65	0.00	3 480	198	8 000	0	11 678	0	11 678
3	Harrow	Magnum Tractor	Apr	0.88	2.80	0.00	4 060	336	8 000	0	12 396	0	12 396
4	Furrow One	T-28 Tractor	Apr	0.75	6.65	0.00	1 160	798	5 000	0	6 958	0	6 958
5	Seed	T-28 Tractor	Apr	1.25	4.00	0.00	1 450	480	5 000	13 500	20 430	0	20 430
6	Irrigate One	By hand	April	0.00	49.50	0.00	0	5 940	0	0	5 940	0	5 940
7	Cultivate One	T-28 Tractor	May	1.50	9.80	0.00	1 450	1 176	5 500	0	8 126	0	8 126
8	Thin	By hand	May	0.00	20.00	25.00	0	6 400	0	0	6 400	0	6 400
9	Furrow Two & Fertilize	T-28 Tractor	May	1.25	9.00	0.00	1 160	1 080	5 000	30 750	37 990	0	37 990
10	Weed One	By hand	June	0.00	24.00	30.00	0	7 680	0	0	7 680	0	7 680
11	Cultivate Two	T-28 Tractor	June	1.25	7.75	0.00	1 160	930	5 000	0	7 090	0	7 090
12	Irrigate Two & Fertilize	By hand	June	0.00	43.50	0.00	0	5 220	0	8 000	13 220	0	13 220
13	Furrow Three & Fertilize	T-28 Tractor	July	1.00	8.20	0.00	1 160	984	5 000	36 900	44 044	0	44 044
14	Cultivate Three	T-28 Tractor	July	1.00	7.20	0.00	1 160	864	5 000	0	7 024	0	7 024
15	Cultivate Four	T-28 Tractor	July	1.00	7.20	0.00	1 160	864	5 000	0	7 024	0	7 024
16	Irrigate Three	By hand	July	0.00	37.50	0.00	0	4 500	0	0	4 500	0	4 500
17	Pest Control (biological)	By hand	July	0.00	2.50	0.00	0	300	0	3 000	3 300	0	3300
18	Weed Two	By hand	Aug	0.00	16.00	0.00	0	1 920	0	0	1 920	0	1 920
19	Furrow Four	T-28 Tractor	Aug	0.75	6.65	0.00	1 160	798	5 000	0	6 958	0	6 958
20	Cultivate Five	T-28 Tractor	Aug	0.75	1.65	0.00	1 160	198	5 000	0	6 358	0	6 358
21	Irrigate Four	By hand	Aug	0.00	31.50	0.00	0	3 780	0	0	3 780	0	3780
22	Cut top of cotton plant	By hand	Aug	0.00	40.00	0.00	0	4 800	0	0	4 800	0	4800
23	Harvest One	By hand	Sep	0.00	65.00	162.50	0	33 800	0	0	33 800	0	33800
24	Harvest Two	By hand	Sep	0.00	30.00	63.00	0	13 680	0	0	13 680	0	13680
25	Transport One	T-28 Tractor	Sep	3.00	14.60	0.00	1 160	1 752	6 000	0	8 912	0	8912
26	Transport Two	T-28 Tractor	Oct	0.75	7.40	0.00	1 160	888	1 000	0	3 048	0	3048
27	Land Taxes	Land Taxes	Ann.	0.00	0.00	0.00	0	0	0	0	0	9 059	9 059
28	WUA Fee	Deliver Water Fee	Ann.	0.00	0.00	0.00	0	0	0	0	0	9 000	9 000
29	Overhead	Utiities, Acct., Legal, Etc.	Ann.	0.00	0.00	0.00	0	0	16 556	0	16 556	0	16 556
	TOTAL:			**17.13**	**458.05**	**280.50**	**27 115**	**99 846**	**109 056**	**111 650**	**347 667**	**18 059**	**365 726**

Table A5. Itemized Cost Per Hectare for Cotton, Every Other Furrow (Surge Flow Irrigation), Namangan Region, Uzbekistan, 2005.

	Unit	Price or Cost / Unit	Quantity	Value or Cost
Variable Costs				
Superphosphate	kg	65	300	19 500
Seeds	kg	225	60	13 500
Nitrogen	kg	123	550	67 650
Organic Manure	kg	2	4000	8 000
Pest Control (biological) - Oltinkuz, Trichogramma	ha	3 000	1	3 000
Renting Machinery	ha	92 500	1	92 500
Machinery Fuel/Lube	ha	27 115	1	27 115
Permanent Labor	hour	120	480	57 666
Seasonal Labor	hour	160	280	44 880
Overhead	ha	16 691	1	16 691
Total Variable Cost				**350 502**
Fixed Costs				
Land Taxes	ha	9 059	1	9 059
WUA Fee	ha	9 000	1	9 000
Total Fixed Cost				**18 059**
TOTAL COST				**368 561**

Cotton yield is assumed to be 25.78 centners/ha.

Cotton price is 25,200 UZS/centner.

Table A6. Schedule of Operations and Estimated Costs Per Hectare for Cotton, Every Other Furrow (Surge Flow) Irrigation, Namangan Region, Uzbekistan, 2005.

#	Operation	Tooling	Month	Mach Hour	Permanent Labor Hour	Seasonal Labor Hour	Variable Cost				Total Variable Costs	Total Fixed Costs	Total Costs
							Fuel, Lube & Repair	Mach Labor	Service	Material			
1	Plow	Magnum Tractor	Nov	1.25	4.00	0.00	5 075	480	19 000	19 500	44 055	0	44 055
2	Land Level	Magnum Tractor	Apr	0.75	1.65	0.00	3 480	198	8 000	0	11 678	0	11 678
3	Harrow	Magnum Tractor	Apr	0.88	2.80	0.00	4 060	336	8 000	0	12 396	0	12 396
4	Furrow One	T-28 Tractor	Apr	0.75	6.65	0.00	1 160	798	5 000	0	6 958	0	6 958
5	Seed	T-28 Tractor	Apr	1.25	4.00	0.00	1 450	480	5 000	13 500	20 430	0	20 430
6	Irrigate One	By hand	April	0.00	55.50	0.00	0	6 660	0	0	6 660	0	6 660
7	Cultivate One	T-28 Tractor	May	1.50	9.80	0.00	1 450	1 176	5 500	0	8 126	0	8 126
8	Thin	By hand	May	0.00	20.00	25.00	0	6 400	0	0	6 400	0	6 400
9	Furrow Two & Fertilize	T-28 Tractor	May	1.25	9.00	0.00	1 160	1 080	5 000	30 750	37 990	0	37 990
10	Weed One	By hand	June	0.00	24.00	30.00	0	7 680	0	0	7 680	0	7 680
11	Cultivate Two	T-28 Tractor	June	1.25	7.75	0.00	1 160	930	5 000	0	7 090	0	7 090
12	Irrigate Two & Fertilize	By hand	June	0.00	49.00	0.00	0	5 880	0	8 000	13 880	0	13 880
13	Furrow Three & Fertilize	T-28 Tractor	July	1.00	8.20	0.00	1 160	984	5 000	36 900	44 044	0	44 044
14	Cultivate Three	T-28 Tractor	July	1.00	7.20	0.00	1 160	864	5 000	0	7 024	0	7 024
15	Cultivate Four	T-28 Tractor	July	1.00	7.20	0.00	1 160	864	5 000	0	7 024	0	7 024
16	Irrigate Three	By hand	July	0.00	43.00	0.00	0	5 160	0	0	5 160	0	5 160
17	Pest Control (biological)	By hand	July	0.00	2.50	0.00	0	300	0	3 000	3 300	0	3300
18	Weed Two	By hand	Aug	0.00	16.00	0.00	0	1 920	0	0	1 920	0	1 920
19	Furrow Four	T-28 Tractor	Aug	0.75	6.65	0.00	1 160	798	5 000	0	6 958	0	6 958
20	Cultivate Five	T-28 Tractor	Aug	0.75	1.65	0.00	1 160	198	5 000	0	6 358	0	6 358
21	Irrigate Four	By hand	Aug	0.00	37.00	0.00	0	4 440	0	0	4 440	0	4440
22	Cut top of cotton plant	By hand	Aug	0.00	40.00	0.00	0	4 800	0	0	4 800	0	4800
23	Harvest One	By hand	Sep	0.00	65.00	162.50	0	33 800	0	0	33 800	0	33800
24	Harvest Two	By hand	Sep	0.00	30.00	63.00	0	13 680	0	0	13 680	0	13680
25	Transport One	T-28 Tractor	Sep	3.00	14.60	0.00	1 160	1 752	6 000	0	8 912	0	8912
26	Transport Two	T-28 Tractor	Oct	0.75	7.40	0.00	1 160	888	1 000	0	3 048	0	3048
27	Land Taxes	Land Taxes	Ann.	0.00	0.00	0.00	0	0	0	0	0	9059	9 059
28	WUA Fee	Deliver Water Fee	Ann.	0.00	0.00	0.00	0	0	0	0	0	9000	9 000
29	Overhead	Utiities, Acct., Legal, Etc.	Ann.	0.00	0.00	0.00	0	0	16 691	0	16 691	0	16 691
	TOTAL:			**17.13**	**480.55**	**280.50**	**27 115**	**102546**	**109 191**	**111 650**	**350 502**	**18 059**	**368 561**

Table A7. Itemized Cost Per Hectare for Cotton, Every Other Furrow (Discrete Flow) Irrigation, Namangan Region, Uzbekistan, 2005.

	Unit	Price or Cost / Unit	Quantity	Value or Cost
Variable Costs				
Superphosphate	kg	65	300	19 500
Seeds	kg	225	60	13 500
Nitrogen	kg	123	550	67 650
Organic Manure	kg	2	4000	8 000
Pest Control (biological) - Oltinkuz, Trichogramma	ha	3 000	1	3 000
Renting Machinery	ha	92 500	1	92 500
Machinery Fuel/Lube	ha	27 115	1	27 115
Permanent Labor	hour	120	526	63 126
Seasonal Labor	hour	160	280	44 880
Overhead	ha	16 964	1	16 964
Total Variable Cost				**356 235**
Fixed Costs				
Land Taxes	ha	9 059	1	9 059
WUA Fee	ha	9 000	1	9 000
Total Fixed Cost				**18 059**
TOTAL COST				**374 294**

Cotton yield is assumed to be 25.78 centners/ha.

Cotton price is 25,200 UZS/centner.

Table A8. Schedule of Operations and Estimated Costs Per Hectare for Cotton, Every Other Furrow (Discrete Flow) Irrigation, Namangan Region, Uzbekistan, 2005.

#	Operation	Tooling	Month	Mach Hour	Permanent Labor Hour	Seasonal Labor Hour	Variable Cost				Total Variable Costs	Total Fixed Costs	Total Costs
							Fuel, Lube & Repair	Mach Labor	Service	Material			
1	Plow	Magnum Tractor	Nov	1.25	4.00	0.00	5 075	480	19 000	19 500	44 055	0	44 055
2	Land Level	Magnum Tractor	Apr	0.75	1.65	0.00	3 480	198	8 000	0	11 678	0	11 678
3	Harrow	Magnum Tractor	Apr	0.88	2.80	0.00	4 060	336	8 000	0	12 396	0	12 396
4	Furrow One	T-28 Tractor	Apr	0.75	6.65	0.00	1 160	798	5 000	0	6 958	0	6 958
5	Seed	T-28 Tractor	Apr	1.25	4.00	0.00	1 450	480	5 000	13 500	20 430	0	20 430
6	Irrigate One	By hand	April	0.00	66.50	0.00	0	7 980	0	0	7 980	0	7 980
7	Cultivate One	T-28 Tractor	May	1.50	9.80	0.00	1 450	1 176	5 500	0	8 126	0	8 126
8	Thin	By hand	May	0.00	20.00	25.00	0	6 400	0	0	6 400	0	6 400
9	Furrow Two & Fertilize	T-28 Tractor	May	1.25	9.00	0.00	1 160	1 080	5 000	30 750	37 990	0	37 990
10	Weed One	By hand	June	0.00	24.00	30.00	0	7 680	0	0	7 680	0	7 680
11	Cultivate Two	T-28 Tractor	June	1.25	7.75	0.00	1 160	930	5 000	0	7 090	0	7 090
12	Irrigate Two & Fertilize	By hand	June	0.00	60.50	0.00	0	7 260	0	8 000	15 260	0	15 260
13	Furrow Three & Fertilize	T-28 Tractor	July	1.00	8.20	0.00	1 160	984	5 000	36 900	44 044	0	44 044
14	Cultivate Three	T-28 Tractor	July	1.00	7.20	0.00	1 160	864	5 000	0	7 024	0	7 024
15	Cultivate Four	T-28 Tractor	July	1.00	7.20	0.00	1 160	864	5 000	0	7 024	0	7 024
16	Irrigate Three	By hand	July	0.00	54.50	0.00	0	6 540	0	0	6 540	0	6 540
17	Pest Control (biological)	By hand	July	0.00	2.50	0.00	0	300	0	3 000	3 300	0	3300
18	Weed Two	By hand	Aug	0.00	16.00	0.00	0	1 920	0	0	1 920	0	1 920
19	Furrow Four	T-28 Tractor	Aug	0.75	6.65	0.00	1 160	798	5 000	0	6 958	0	6 958
20	Cultivate Five	T-28 Tractor	Aug	0.75	1.65	0.00	1 160	198	5 000	0	6 358	0	6 358
21	Irrigate Four	By hand	Aug	0.00	48.50	0.00	0	5 820	0	0	5 820	0	5820
22	Cut top of cotton plant	By hand	Aug	0.00	40.00	0.00	0	4 800	0	0	4 800	0	4800
23	Harvest One	By hand	Sep	0.00	65.00	162.50	0	33 800	0	0	33 800	0	33800
24	Harvest Two	By hand	Sep	0.00	30.00	63.00	0	13 680	0	0	13 680	0	13680
25	Transport One	T-28 Tractor	Sep	3.00	14.60	0.00	1 160	1 752	6 000	0	8 912	0	8912
26	Transport Two	T-28 Tractor	Oct	0.75	7.40	0.00	1 160	888	1 000	0	3 048	0	3048
27	Land Taxes	Land Taxes	Ann.	0.00	0.00	0.00	0	0	0	0	0	9059	9 059
28	WUA Fee	Deliver Water Fee	Ann.	0.00	0.00	0.00	0	0	0	0	0	9000	9 000
29	Overhead	Utiities, Acct., Legal, Etc.	Ann.	0.00	0.00	0.00	0	0	16 964	0	16 964	0	16 964
	TOTAL:			**17.13**	**526.05**	**280.50**	**27 115**	**108006**	**109 464**	**111 650**	**356 235**	**18 059**	**374 294**

Table A9. Itemized Cost Per Hectare for Winter Wheat, Traditional Furrow Irrigation, Namangan Region, Uzbekistan, 2005.

	Unit	Price or Cost / Unit	Quantity	Value or Cost
Variable Costs				
Superphosphate	kg	65	500	32 500
Seeds	kg	240	250	60 000
Nitrogen	kg	123	500	61 500
Chemicals - Granstar	ha	300 000	0.02	6 000
Renting Machinery	ha	67 000	1	67 000
Machinery Fuel/Lube	ha	14 935	1	14 935
Permanent Labor	hour	120	138	16 592
Seasonal Labor	hour	160	0	0
Overhead	ha	12 926	1	12 926
Total Variable Cost				**271 454**
Fixed Costs				
Land Taxes	ha	9 059	1	9 059
WUA Fee	ha	9 000	1	9 000
Total Fixed Cost				**18 059**
TOTAL COST				**289 513**

Winter wheat yield is assumed to be 34.9 centners/ha.

Price of winter wheat sold to the state organization is 25,200 UZS/centner and on the market is 11,000 UZS/centner.

Table A10. Schedule of Operations and Estimated Costs Per Hectare for Winter Wheat, Traditional Furrow Irrigation, Namangan Region, Uzbekistan, 2005.

#	Operation	Tooling	Month	Mach Hour	Permanent Labor Hour	Seasonal Labor Hour	Variable Cost				Total Variable Costs	Total Fixed Costs	Total Costs
							Fuel, Lube & Repair	Mach Labor	Service	Material			
1	Fertilize One	T-28 Tractor	Oct	1.33	4.27	0.00	1 160	512	5 000	32 500	39 172	0	39 172
2	Cultivate One	T-28 Tractor	Oct	1.00	2.20	0.00	1 450	264	6 000	0	7 714	0	7 714
3	Seed	T-28 Tractor	Oct	1.33	4.27	0.00	1 450	512	6 000	60 000	67 962	0	67 962
4	Cultivate Two	T-28 Tractor	Oct	1.00	2.20	0.00	1 450	264	6 000	0	7 714	0	7 714
5	Irrigate One	By hand	Oct	0.00	24.00	0.00	0	2 880	0	0	2 880	0	2 880
6	Irrigate Two	By hand	Mar	0.00	20.00	0.00	0	2 400	0	0	2 400	0	2 400
7	Fertilize Two	T-28 Tractor	Mar	1.67	13.33	0.00	0	1 600	0	30 750	32 350	0	32 350
8	Chemical Application	By hand	Apr	0.00	10.67	0.00	0	1 280	0	6 000	7 280	0	7 280
9	Irrigation Three	By hand	Apr	0.00	20.00	0.00	0	2 400	0	0	2 400	0	2 400
10	Fertilizer Three	T-28 Tractor	Apr	1.67	13.33	0.00	0	1 600	0	30 750	32 350	0	32 350
11	Irrigate Four	By hand	May	0.00	16.00	0.00	0	1 920	0	0	1 920	0	1 920
12	Harvest	Case Combine	Jun	0.83	2.67	0.00	3 625	320	40 000	0	43 945	0	43 945
13	Transport	Kamaz Truck	Jun	1.67	5.33	0.00	5 800	640	4 000	0	10 440	0	10 440
14	Land Taxes	Land Taxes	Ann.	0.00	0.00	0.00	0	0	0	0	0	9059	9 059
15	WUA Fee	Deliver Water Fee	Ann.	0.00	0.00	0.00	0	0	0	0	0	9000	9 000
16	Overhead	Utiities, Acct., Legal, Etc.	Ann.	0.00	0.00	0.00	0	0	12 926	0	12 926	0	12 926
	TOTAL:			**10.50**	**138.27**	**0.00**	**14 935**	**16 592**	**79 926**	**160 000**	**271 454**	**18 059**	**289 513**

Table A11. Alternative Irrigation Activities for Cotton

NIR[a]	Irrigation Efficiency	Applied Water in Period 4	Wheat Yield Index	Wheat Yield	Irrigation Labor	Perma-nent Labor	Seasonal Labor	Total Variable Cost[b]
%	%	m^3/ha	%	Centner /ha	hr/ha	hr/ha	hr/ha	1,000 UZS/ha
100	53	7 716	100	23.2	156	247	255	336
100	60	6 816	111	25.8	202	256	281	348
100	68	6 014	111	25.8	225	256	281	351
100	70	5 842	111	25.8	270	256	281	356
90	53	6 944	94	21.8	156	241	239	332
90	60	6 134	104	24.2	202	250	269	345
90	68	5 413	104	24.2	225	250	267	348
80	53	6 173	88	20.4	156	244	223	330
80	60	5 453	98	22.7	202	247	249	341
80	68	4 811	98	22.7	225	247	249	344
70	53	5 401	82	19.0	156	248	206	327
70	60	4 771	91	21.1	202	256	231	338
70	68	4 210	91	21.1	225	256	231	341
60	53	4 630	76	17.6	156	243	190	322
60	60	4 090	84	19.6	202	250	213	335
60	68	3 608	84	19.6	225	250	213	337

[a]Net Irrigation Requirement (NIR).
[b]Including labor costs for permanent labor at 120 UZS/hr and seasonal labor at 160 UZS/hr.

Table A12. Alternative Irrigation Activities for Winter Wheat

NIR[a]	Irrigation Efficiency	Applied Water	Wheat Yield Index	Wheat Yield	Irrigation Labor	Perma- nent Labor	Seasonal Labor	Total Variable Cost[b]
%	%	m^3/ha	%	centner/ha	hr/ha	hr/ha	hr/ha	1,000 UZS/ha
100	53	6 421	97	34.9	80	58	0	271
100	60	5 672	98	35.3	92	58	0	273
100	68	5 005	99	35.6	105	58	0	275
100	70	4 862	100	36.0	108	58	0	275
90	53	5 779	97	34.9	90	58	0	272
90	60	5 105	98	35.3	104	58	0	274
90	68	4 504	99	35.6	119	58	0	276
90	70	4 376	100	36.0	123	58	0	277
80	53	5 136	87	31.3	73	58	0	269
80	60	4 537	88	31.7	84	58	0	271
80	68	4 003	89	32.0	97	58	0	272
80	70	3 889	90	32.4	100	58	0	273
70	53	4 515	77	27.7	58	58	0	266
70	60	3 988	78	28.1	67	58	0	267
70	68	3 519	79	28.4	77	58	0	269
70	70	3 419	80	28.8	79	58	0	269

[a]Net Irrigation Requirement (NIR).
[b]Including labor costs for permanent labor at 120 UZS/hr and seasonal labor at 160 UZS/hr.

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