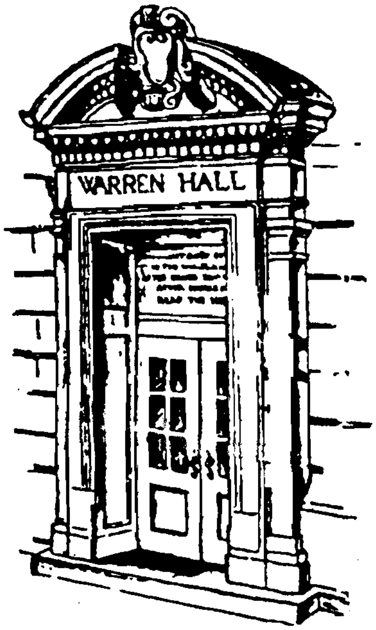

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Agricultural Land Use in Northwest Uzbekistan:
A Linear Programming Model for Mapping Agricultural Incentives

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ABSTRACT

This study uses a linear programming model of a representative state farm in the region Karakalpakstan in the republic of Uzbekistan to evaluate how producer incentives and cropping patterns may change given both changes in state pricing policy and changes in the availability and cost of irrigation water.

Cotton has long been the dominant crop in this area, and Uzbekistan is currently the world's second largest exporter. Cotton production has expanded tremendously over the past 30 years almost entirely through the extension of very large state sponsored irrigation projects. However, despite large investments and production increases, productivity and efficiency remain low. Agriculture in the region is characterized by state control at all levels of agricultural production, while extensive cotton monocropping has created a myriad of environmental problems that have attracted international attention. Should policy reforms be implemented in the form of the removal of state controls together with changes in water management, it is likely that relative incentives for the production of major crops would change significantly.

There are two primary objectives of this paper. First is an evaluation of how production incentives for different crops change as state intervention in the agricultural sector is reduced and/or eliminated. Second, the study evaluates how producer incentives change based on different assumptions about the availability and cost of irrigation water which at present is provided free of charge.

Results indicate that if state interventions were to be reduced, there would not necessarily be a significant change in cropping patterns from those currently practiced. However, a supply function for cotton output is generated and shows an elasticity consistently greater than one indicating that, at least according to model parameters, area planted to cotton is highly responsive to changes in output price. Results also demonstrate that the elimination of state intervention may not result in an increase in farm income which indicates that taxes extracted from the sector in the form of low prices for farm output are, at least to a first order

of approximation, offset by subsidies for other farm inputs which occur mostly in the form of no fee for irrigation water. Model results also demonstrate that changes in water availability have a significant impact on the optimal cropping pattern. With large quantities of water available rice production is favored. However, with reduced quantities of water, the optimal cropping pattern quickly shifts away from rice toward other less water consumptive crops. Model results also indicate that the marginal value product of water is significantly positive, indicating that implementing fees would not necessarily cause producers to alter existing cropping patterns. A version of Rybczinski's theorem is shown to hold for the relation between water availability and there area planted to water intensive crops.

Introduction

The autonomous region of Karakalpakstan covers an area of 2.5 million ha. and lies in the northwest region of Uzbekistan. The region contains the southern border of the Aral Sea, and the Amu Darya river delta. Of this 2.5 million ha. of total land, only 312,000 ha. is arable, resulting in a land availability of .28 ha. per capita. Rainfall in the region averages approximately 300 mm per annum and as a result nearly all agriculture is dependent on irrigation. The region is the poorest in the Republic and largely lags behind other regions of Uzbekistan in terms of social and economic indicators. Karakalpakstan is also the region of Uzbekistan that has been hardest hit by the environmental catastrophe of the drying up of the Aral Sea. This environmental disaster has been a calamity for the people of the region both in terms of public health and in terms of threatening the future of agriculture.

Agricultural production in Karakalpakstan has expanded tremendously over the past 30 years almost entirely by the transformation of desert regions into arable lands through the extension of state sponsored irrigation projects. However, despite large investments and production increases, productivity and efficiency for agriculture remain low, with virtually all growth coming from area expansion and not yield improvements. Moreover, extensive cotton monocropping has created a myriad of environmental calamities that have attracted international attention.

Agriculture in the region is characterized by a very large degree of state control at all levels of agricultural production and marketing and operates in much the same way it did prior to the breakup of the USSR. However, should market oriented reforms be implemented in the sector it is possible that relative incentives for the production of major crops would change significantly. This paper will provide a survey of the major policies affecting agriculture and land use in Karakalpakstan and will use a linear programming model of a representative state farm to evaluate how changes in economic and environmental policy would affect incentives for farm producers.

Table 1. Agricultural Land Use in Karakalpakstan: Percent of Land Area by Crop

	1991	1992	1993	1994	1995	1996
Lint Cotton	52.2	49.6	49.4	46.9	49.9	47.0
Grains Total	39.1	42.2	44.1	46.8	43.3	46.4
Rice	31.0	33.9	33.3	29.9	31.6	32.1
Wheat	2.7	3.0	5.0	12.7	6.8	10.9
Other Grains	5.4	5.3	5.8	4.2	4.9	3.4
Potatoes	0.6	0.5	0.6	0.6	0.7	0.6
Vegetables	2.4	2.7	2.7	2.5	2.8	2.6
Melons	4.6	3.8	2.3	2.3	2.3	2.3
Fruits	1.0	1.0	0.9	0.8	0.9	0.9
Grapes	0.1	0.1	0.1	0.1	0.1	0.1
Total Fruits and Vegetables	8.1	7.6	6.0	5.7	6.1	5.9

Source: Karakalpakstan Ministry of Agriculture

The Agricultural Sector in Karakalpakstan

Table 1 shows arable land use patterns in Karakalpakstan since independence. It is evident from the table that land use is dominated by the production of cotton and graincrops. Since 1991, the total area devoted to cotton decreased slightly from 52.2% to 47% of total land area. However, the area devoted to wheat increased from 2.7% in 1991 to 10.9% of total land area as a result of an effort on the part of the central government to achieve food grain self sufficiency. Under the soviet structure, nearly all grain needs for the republic were supplied by neighboring Kazakstan and Russia. Since independence however, government policy has explicitly focused on increasing land areas devoted to grain production for the purpose of reducing if not eliminating food grain imports. This increase has been more substantial in other parts of the country but it is nevertheless evident that part of the responsibility of achieving food grain self sufficiency has fallen on Karakalpakstan. The question of the efficacy of this policy is not the focus of this study. Nevertheless it is quite likely that as Uzbekistan's comparative advantage lies in cotton production, greater levels of aggregate income could be achieved were Uzbekistan to concentrate on cotton production and import wheat from Kazakstan which holds a comparative advantage in grain production.

Fruit and vegetable production has remained relatively constant during the period. While fruits and vegetables occupied just under 6% of total land area in 1996, this sector represents an important component of agricultural production due to the high value of these privately marketed crops. Many observers have noted that expanded production of horticultural crops could prove very useful in enabling Uzbekistan to diversify its mix of exports and help to relieve its great dependence on cotton as its main export commodity.

Significant export markets for fresh market fruits and vegetables may exist for Uzbekistan in Russia and other parts of the Former Soviet Union. However, given the significant distances and transportation costs, it is unlikely that Uzbekistan is presently in any position to compete in Western European markets with other traditional fresh fruit exporters such as Israel and Turkey. These competing countries have relatively lower transport costs and more experience with Western quality control requirements. Over the medium term, it is likely that Russia and other neighboring republics will constitute the most viable export market for Uzbek horticultural products.

Nearly all cotton grown in Karakalpakstan and Uzbekistan is exported as raw cotton. Prior to independence, cotton textile manufacture was performed in other parts of the Soviet Union, but since independence planners have expressed interest in developing domestic textile industries. While a small number of textile facilities have been constructed during the past five years, investment in these industries has not been sufficient to have a significant impact on the structure of the sector and it is likely to take some time for Uzbekistan to achieve the levels of consistency and quality required by the international market. Accordingly, for the time being Uzbekistan must look to the world raw cotton market for export earnings, while using domestic textile production to satisfy internal demand.

Crop yields in Karakalpakstan are generally lower than in other parts of Uzbekistan, and are substantially lower than in other parts of the world. As can be seen in Table 2, crop

Table 2. Average Crop Yields for Cotton, Rice, and Wheat 1994-1996 (tons/ha)

	Karakalpakstan	Uzbekistan	Egypt	Turkey	India
Seed Cotton	2.1	2.5	2.6	2.8	.9
Rice	1.8	3.1	7.9	5.1	2.9
Wheat	1.2	1.3	5.2	1.9	2.4

Source: Ministry of Agriculture Karakalpakstan; FAO Production Yearbook

yields for cotton in Karakalpakstan have averaged 2.1 tons/ha. over the past 3 years in contrast to 2.5 tons/ha. for the rest of Uzbekistan. Lint quality notwithstanding, yields in Uzbekistan compare rather favorably to those in Egypt and Turkey and are considerably more favorable than those in India over this period. Rice production in Karakalpakstan suffers from very low yields, though since very little rice is grown in other parts of Uzbekistan it is not useful to make a comparison between the two. We can see however, that rice yields in Karakalpakstan are considerably lower than other producing nations who are at a similar stage of development and who face similar agroclimatic conditions. Similarly, yields for wheat also lag far behind those obtained in the compared countries.

Low yields for these major crops are partly due to the generally low levels of productivity that were prevalent in all soviet agriculture. However, it should also partly be attributed to the environmental degradation resulting from deterioration in water quality and the drying up of the Aral Sea. It is expected that substantial improvements could be made to the agricultural system in terms of productivity should questions of water quality be resolved, and effective reforms be made to improve producer incentives.

Irrigation Management

Perhaps no other resource is as critical and constraining a factor for agriculture in Karakalpakstan as water. In the absence of irrigation water little if any agricultural activity is possible. At present over 90% of cultivated land in Karakalpakstan is irrigated. Farmers, farm directors and ministry officials repeatedly point to the critical importance of water for agriculture. "With water we can have everything; without water there will be nothing" stated one state farm director. In a more drastic tone another remarked, "We need water more than we need air".

Irrigation management is controlled by the Ministry of Agriculture and Water Resources, which determines the level and flow rate of water in main and interfarm canals at the regional level. State farms are responsible for the maintenance of on-farm irrigation and drainage canals. It is important to note that there is no direct economic relationship between the Ministry of Agriculture and Water Resources and state farms and other agricultural producers. Expenses for the supply of irrigation water and for the maintenance of irrigation infrastructure are covered through budgetary allocations of the central government. Producers use irrigation water as needed without regard to its cost. This has been a major factor for the grossly inefficient water use strategies employed by producers, and explains the very large quantities of irrigation water used on crops in Uzbekistan. Table 3 shows typical water use rates in Uzbekistan compared to water use for cotton in other countries with similar agroecological conditions.

Table 3. Irrigation Water Use for Cotton: Selected Countries

	Uzbekistan	Syria	Egypt	California
Water Use 1,000m^3/ha.	12.8	7.4	8.5	9.2
kg lint/1000m^3 water	64.4	152.6	124.4	160.1

"Land and Water Policies in Uzbekistan", Lerman, Garcia-Garcia, and Wichelns

It is clear that the intensity of water use for cotton in Uzbekistan is considerably greater than in other regions while the productivity of irrigation water with respect to its contribution to yield is considerably lower. Excessive application of irrigation water has led to severe soil salinization, a problem which has been greatly exacerbated by the poor quality of drainage infrastructure on farms as well as generally shallow groundwater tables which in many areas lie only 2-3 meters below the soil surface. Soil salinization has become such a problem in many areas that producers have adopted the strategy of attempting to 'wash' the soil prior to planting. Large quantities of irrigation water are applied at the beginning of the growing season in order flush salts down and away from the root horizon. Subsequently irrigation water is applied sparingly in order that the crop may have sufficient water throughout the growing season. However, it effectively becomes a race against time for many producers to obtain a harvestable crop before the irrigation water percolating down into the soil facilitates the return of salts back up to the root horizon where it then becomes a major hindrance to plant development.

It is not certain how long such a production practice can be maintained. Moreover, it is also not clear that there is a direct solution to this problem of soil and water salinization[1]. Most of the salts contained in irrigation water coming to Karakalpakstan are contracted as runoff from farms in upstream regions. Barring a major change in cropping and irrigation management practices on the part of upstream producers, it is unlikely that the quality of irrigation water flowing to Karakalpakstan will change significantly. Moreover, on this point it should be noted that much of the salts in the irrigation water reaching Karakalpakstan are not from agrochemicals, but from salts dissolved into irrigation water which occur naturally in the soils upstream. Hence, a simple reduction in the use of agrochemicals will not have the result of reducing salt levels in water reaching Karakalpakstan. Only a drastic reduction in the use of irrigation water upstream would have a measurable impact on the quality of water reaching Karakalpakstan, and this would still not resolve the issue of salinization occurring from salts contained in the soil in Karakalpakstan itself.

However, despite the fact that soil salinization will continue to plague producers in Karakalpakstan, there are nevertheless a number of actions that could be taken that would ameliorate this problem at least somewhat. The first would be to switch to crops with lower water requirements. Both of the main crops presently grown in Karakalpakstan, cotton and rice, generally use significant quantities of irrigation water. A switch to orchards and other crops with lower water requirements could serve to significantly improve upon this problem.

Also, while large investments have been made in the development of irrigation canals, there has not always been a corollary investment in drainage infrastructure. It is clear that lack of drainage canal infrastructure has contributed significantly to the problem of both soil salinization and deterioration of soil productivity. Indeed, in the fields of many state farms there is no drainage system in place at all. Hence all water applied necessarily will percolate down into the soil and result in the return of salts back to the soil surface.

It should also be noted that under the current policy environment, ownership of land is nonexistent and property rights and responsibilities for stewardship of land are poorly defined. As such there is little if any incentive for state farm workers to maintain on-farm canal infrastructure. Certainly farm workers are ostensibly responsible, but as returns to this activity do not accrue directly to the agent that makes this investment in terms of labor, there is little incentive for farm workers to devote great efforts to ensure that drainage systems are operating effectively.

Another important factor that needs to be considered is that since there is no charge for the use of irrigation water, there is little incentive to economize or use water efficiently. In fact in Uzbekistan water is viewed as a free good that should not require payment. This attitude was promoted by soviet state structures which lauded their ability to provide water and other public utilities at no cost to the user. As a result of these historical experiences, there are significant cultural and social forces in place that work against the implementation of fee structures for the use of irrigation water[2]. It should be noted however, fees for water were in fact a characteristic of agriculture in Central Asia prior to soviet control. Nevertheless for future planning purposes, due in no small part to the legacy of soviet control, any water policy reform strategy which attempts to redefine economic relationships between costs and user will invariably have to take these social factors into consideration.

A Model of Land Use in Karakalpakstan

This study uses a linear programming (LP) model for a representative state farm to evaluate changes in producer incentives resulting from reforms in agricultural and environmental policy. As state farms in Karakalpakstan tend to be relatively homogeneous, a representative farm model is a useful analytical framework with which to model these policy changes. Given the small degree of variability between state farms, results obtained from the representative farm model can reasonably be applied to develop hypotheses regarding incentive structures in the agricultural sector as a whole.

The primary questions that this linear programming model serves to evaluate are:

a) How would cropping decisions change if the current state run system were liberalized and farmers faced market prices for inputs and output?

b) How would optimal cropping allocations change based on different assumptions about the cost and availability of irrigation water?

The model maximizes net farm income subject to constraints of land, labor, water and capital availability. A series of farm budgets were constructed for all crops included in the model using both observed domestic prices and border price estimates for farm inputs and output. Each farm budget represents the return generated by that crop on a per hectare basis. Crops included in the model include cotton, rice, winter wheat, spring wheat, alfalfa, maize, melons, and tomatoes. For all crops, variable costs were subtracted from total revenues to obtain an estimate of net income per unit of land for that crop.

Total revenue in the farm budget consists of the output price of the crop multiplied by the expected yield on a per hectare basis. In some instances the sale of the byproduct of the crop was also included in the revenue component of the farm budget. Variable costs consist of seed, fertilizer, manure, machinery, irrigation water, and labor. The price of the input was multiplied by the quantity used on a per hectare basis to obtain an expense estimate per hectare for that input.

Domestic Price vs. Border Price Farm Budgets

The farm budgets for all crops in the model have been estimated using both current domestic prices and border price estimates. A farm budget which uses border prices gives an indication of what the relative profitability of different crops would be in the absence of state intervention in input and output markets. Presently, the state supplies farm inputs at controlled prices and maintains procurement orders for many agricultural commodities at a price which differs substantially from prices that prevail on world markets or in neighboring countries. A farm budget that uses border price estimates for farm inputs and output can be used to evaluate the relative profitability of different crops in the absence of price distortions. This provides an indication of how production incentives are likely to change with a lower degree of state intervention in the agricultural sector.

The border price of a good is equal to the world price of that good adjusted for transportation and marketing costs. If the good is imported, then the border price is equal to the world price of the good plus the transport and marketing margins involved in getting it to the farm gate, while if it is exported, the border price is the world market price of that good less the transport and marketing costs involved in getting the good to the farmgate. For an exported tradable such as cotton in Karakalpakstan, this is effectively an estimate of the farmgate price that a producer would receive in the absence of any price distortions or state intervention in the market. For potentially imported goods such as wheat, border prices are derived from the selling prices of potential suppliers (e.g. Kazakstan) with the addition of associated transport costs. The border price thus represents an efficiency benchmark which can be contrasted with existing domestic prices to establish whether producers are receiving a tax or a subsidy in the price of different elements of their farm inputs and output.

A shadow price represents an estimate of the opportunity cost of a good that is not tradable. It is an estimate of the value of the good in its next best alternative use. For instance, in the context of Karakalpakstan, water is a nontraded farm input with an observed on farm price of zero. However, if we gather information as to the costs involved to provide irrigation water, it is possible to estimate a shadow value for the use of that input.

All data for this study were obtained during a visit to Uzbekistan in the Spring and Summer of 1997. The methodology for data collection consisted of numerous interviews with state officials in the Ministry of Agriculture and Water Resources and other relevant ministries. On farm data was obtained through a series of visits to 17 different farms where directors, managers and state farm workers were queried with regard to their cropping practices, resource endowments and marketing arrangements. Lastly, this study also relies on secondary data obtained from other technical assistance projects whose work pertains to the Uzbek agricultural sector.

Data for seed application rates and prices, both domestic and border, were obtained through field interviews and through secondary data sources. Fertilizer prices and application rates were obtained through discussions with the state agrochemical supplier Uzagrochemservice and on farm interviews. The border prices for fertilizers were taken from 'Commodity Markets and the Developing Countries' published by the World Bank. For machinery costs, and hourly cost of operation was derived for both heavy caterpillar and light wheeled tractors, as well as farm implements and harvesting machinery. Hourly cost of operation was dependent upon the purchase price, the estimated useful life of the machine, the cost of capital, and the fuel requirements for the machine for each operation. Information regarding machinery requirements by crop was also obtained from field interviews and secondary data sources.

Data concerning water requirements for each crop was obtained through discussions with the state water research institute SANIIRI and interviews with state farm managers. The shadow price of water of $3.33 per 1,000 cubic meters was the unit cost which SANIIRI estimated would be needed to cover state expenditures for the provision of irrigation water. Estimates for labor requirements were taken as an average of field interviews and secondary data sources. The wage rate was taken as the average wage rate at the time of field interviews.

Data for yield and output price data was taken as a result of interviews with state farm management and data provided by the Ministry of Agriculture. Border price estimates for major traded commodities such as cotton and grains were taken from "Commodity Markets and the Developing Countries with transportation and processing cost estimates included. Border price estimates for other commodities were taken from secondary sources.

Lastly, all price data for farm budgets was initially collected in the Uzbek currency som. It was then converted at the official state exchange rate prevailing in July 1997 of 61 som/$. To establish the shadow price of nontradables such as labor, these inputs were converted to a dollar value at the estimated shadow exchange rate of 100 som/$.

Description of Representative Farm and Construction of the Linear Programming Model

The programming model maximizes net farm income subject to the constraints of land, labor, water, and capital. The complete programming model with a glossary of notation for all variables using domestic prices is contained in Appendix A. The objective function of the linear programming model contains the total revenue obtained for each crop. It also contains values for the costs associated with fertilizer and machinery expenses. Labor and water were included as constraints in the initial formulation of the model. This was done initially to use the linear programming model to derive dual values for these farm inputs by varying labor and water availability. However, these inputs are included as objective function coefficients in subsequent formulations of the model in order to test different assumptions regarding the relative cost of these inputs.

Technical requirements for crops such as the estimated number of labor days, quantity of irrigation water, and hourly machinery requirements were placed as technical coefficients in the constraint section of the model. In the case of labor and water, the supply available for these resources was divided into monthly periods given the seasonal nature of their use and availability. For other resources such as fertilizer and machinery this was not necessary since availability is relatively constant through the year.

Description of The Representative Farm

A summary of the general characteristics and parameters of the representative farm are contained in Table 3. The farm has 1500 hectares of irrigated land. In the initial formulation, there are 48,000,000 cubic meters of water available to the farm over the course of the growing season. Water availability is divided up by month, and monthly water requirements by crop are placed as technical coefficients in different period constraints of the model.

Table 3 Parameters of Representative Farm

Arable Land	1,500 hectares
Water Available (initial)	48,000,000 m3

Labor	550 workers at 22 work days/month
Machinery	25 Altai Caterpillar tractors 40 MTZ 80 Wheeled Tractors 20 Harvester Combines
Crop Selection	Cotton, Rice, Spring Wheat, Winter Wheat, Alfalfa, Maize, Melons, and Tomatoes

The crops to be grown consist of cotton, rice, spring wheat, winter wheat, alfalfa, maize, tomatoes, melons, and pasture. With the exception of winter wheat, all crops are grown in the Summer, planted in April and May and harvested in the late Summer or Fall. There is an overlap, however, in Spring and Fall with the winter wheat rotation for labor and water requirements. As alfalfa is commonly grown in rotation with both cotton and wheat, two constraints were placed to require a 3 year cotton 2 year alfalfa rotation and a 3 year rice 1 year alfalfa rotation, corresponding to common field practices.

For labor it is assumed that there are 550 workers on the farm who are able to work 22 days per month resulting in 12,100 man days of labor available in a given month*. Labor requirements rise significantly during the periods of planting and harvest, particularly for cotton. The estimated total labor requirement for cotton for a growing season is 93 days per hectare, much of this being required for the hand harvesting of the crop. In practice, this results in a great deal of extra labor being allocated to the state farm for cotton planting and harvest as 'extra' household labor available on the state farm is mobilized during this period. State farm children are generally expected to work in the fields during planting and harvest, while urban and township students are also mobilized during the Fall and taken to the state farms to aid with the harvest. To account for this increase in labor availability, the right hand side constraint on labor is increased by 50% for the planting months of April, May, and for the harvest months of September and October.

* This level of labor corresponds to that reported during field interviews.

In addition to extra labor supplied by other household members and imported student labor, we also assume that it is possible to purchase additional day labor at a price of $4.00 per day which was the daily wage reported during field interviews. However, the availability of extra farm labor is limited. As a result we have limited the amount that the farm can purchase to a total of an additional supply of 12,100 man days, which is the equivalent of an additional month of labor availability for the farm, or 12% of the total available labor supply for the farm during the growing season. This assumption is reasonable as there is a fair degree of labor traded both formally and informally between farms.

Results

Table 4 shows the optimal cropping pattern for the initial run of the model using domestic prices for all farm inputs and output. It can be seen from the table that in the initial model formulation, the farm will grow 500 ha. of winter wheat. The farm will also plant 244 ha. to cotton, 554 ha. to rice, and 185 ha. to alfalfa. In this formulation no area is planted to spring wheat or maize. The allowable increase for these crops is 68.83 and 43.51 respectively which means that the gross margin for these crops would have to increase by this much before they would start to be planted on the representative farm. Finally, the reader will recall that a maximum area constraint was placed on high output price melons and tomatoes; as these constraints are both binding, the allowable increase for these variables is infinity.

Table 4. Initial model Results: Cropping Pattern Using Domestic Prices

Crop	Hectares	Obj. Fnctn. Value	Allowable Increase	Allowable Decrease
Cotton	244	564	27	26
Spring Wheat	0	244	44	Infinity
Winter Wheat	500	279	Infinity	14
Rice	554	856	79	144

Alfalfa	185	218	47	431
Maize	0	279	69	Infinity
Melon- High Output Price	200	511	Infinity	197
Melon- Low Output Price	0	256	58	Infinity
Tomato- High Output Price	50	497	Infinity	187
Tomato- Low Output Price	0	249	61	Infinity
Pasture	269	20	34	19

Values for the allowable increase or decrease of objective function values in the last two columns of Table 4 indicate that model results are relatively robust. The objective function value for rice (presently 856) would have to increase by 144 or decrease by 79 before there would be a change in the existing cropping pattern. Since the constraints for winter wheat, and high output price melons and tomatoes are binding, the allowable increase for these crops is infinity. The allowable decrease for these crops however is substantial, which indicates that there would have to be a substantial change in either price or yield to alter model results. The allowable decrease for winter wheat however is only 14. As this crop competes for both water and labor in the spring and fall, a slightly different assumption about the productivity of this crop may produce a different result.

Interestingly, the model results for cotton are relatively sensitive. With an objective function value of 564, the allowable increase is 27, and decrease only 26. This means that with only a slight change in yield or price received, cotton area would change. An increase in yield only slightly better than the assumed 2.3 ton/ha would result in greater areas planted to cotton.

In order to analyze this result further, the objective function value of cotton was increased beyond the allowable increase to 591 from its initial value of 564 resulting in an increase in the area planted of 12% (from 244 to 274 ha.). By calculating a simple arc elasticity it was found that the implied supply elasticity for cotton was 2.4 at this level of production. Subsequent permutations of the model were run further increasing and decreasing the objective function value according to allowable ranges to estimate a supply curve for cotton, and to evaluate how the supply elasticity would change with further alterations of the objective function value. For all model results the supply response elasticity was greater than 1 indicating that, at least under the parameters specified by the model, area planted to cotton is very responsive to changes in price. It is also interesting to note that the arc elasticity value calculated between the existing domestic price and the estimated border price was 2.55, which indicates that were the output price for cotton to be raised to a level at or near the border price, there would be incentives to expand the area planted to cotton significantly. A step function showing the supply response for cotton is contained below in Figure 1.

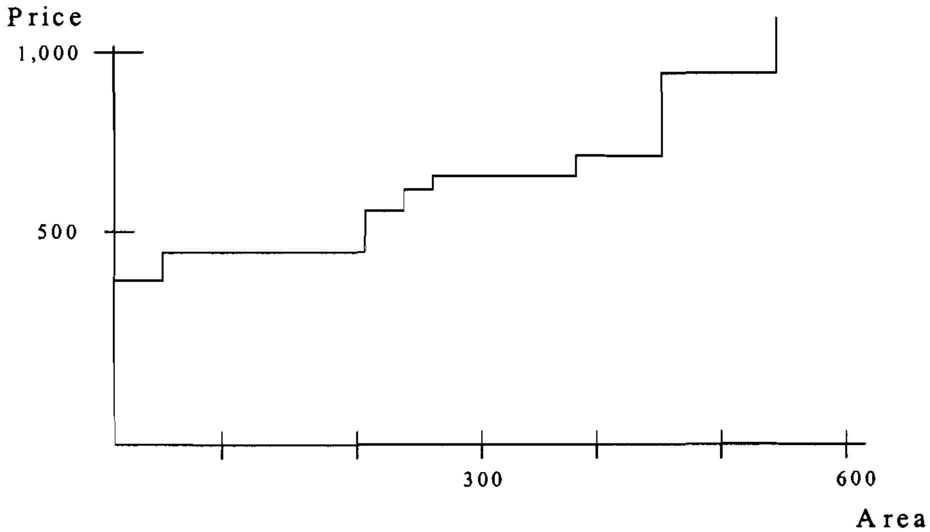

Figure 1. Cotton Supply Response Function

Interestingly, the results obtained from the initial formulation of the model differ rather significantly from existing cropping practices on state farms. Results from field interviews indicated that commonly, 2/3 of land on the state farm will be devoted to the production of cotton and grain with this area being split nearly evenly between the two crops. One third of total area will be sown to cotton, and one third to grain, be it rice or spring wheat, with the remaining third of the total area being composed of an assortment of other crops. For the case of rice, model results are similar to existing practices. 554 ha. planted to rice is roughly equivalent to 1/3 of planted area. The area planted to cotton however is significantly less in the model results than in existing practices. This result confirms the hypothesis that cotton suffers from a discriminatory output price policy. Or put another way, in the absence of a state procurement order for cotton, under existing price structures producers would have incentives to grow significantly less cotton than at present.

Programming Results Using Border/Shadow Prices for Farm Inputs and Output

In order to evaluate the effects of a liberalization program, the model was rerun using border and shadow price values as described above. The technical coefficients related to fertilizer application rates and labor requirements remain the same. It is worth noting however, that for this permutation, water was added as a cost variable in the objective function at a price of 3.33$/1,000m^3 which is the unit cost estimated by Uzbek ministry officials that would cover state expenditures for the provision of irrigation water.

Table 5 shows the model results using border and shadow prices. For ease of comparison, the results of the initial formulation using domestic prices have been placed next to the border price model results, demonstrating that cropping patterns change significantly

Table 5. Model Results Using Border and Shadow Prices

Crop	Border Price Formulation Hectares	Initial Formulatio n Hectares	Change
Cotton	458	244	+214
Spring Wheat	0	0	0
Winter Wheat	500	500	0

Rice	488	554	-66
Alfalfa	305	185	+120
Maize	0	0	0
Melon- High Output Price	200	200	0
Melon- Low Output Price	0	0	0
Tomato- High Output Price	50	50	0
Tomato- Low Output Price	0	0	0
Pasture	0	269	-269

using border prices. We can see that the area planted to cotton has nearly doubled from 244 ha. in the initial formulation to 458 ha. in the formulation using border and shadow prices. The acreage planted to rice has decreased from 554 ha. in the initial formulation to 488 ha. in this formulation. Area planted to alfalfa has increased from 185 ha. to 305 ha. This, however, is due to the constraint which requires that alfalfa be planted as a rotation 2 years in a 5 year cropping cycle with cotton. Areas planted to high output price melons and tomatoes do not change, remaining constant at 200 and 50 ha respectively. However, the area devoted to fallow pasture has decreased significantly from 269 ha. to 0 ha. in this formulation. This is an understandable result since generally the return using border and shadow prices for all crops is higher than the return using domestic prices, this would result in less land being left for pasture.

It is also worth noting that the cropping pattern in this formulation of the model far more closely resembles existing cropping patterns than does the initial model formulation that uses domestic prices. This result is very significant. For from this we can conclude that present cropping patterns potentially represent an optimal use of agricultural resources for the economy at large though producers would not voluntarily choose this crop mix under current state determined prices. An important caveat should be included in this statement: This result also assumes that supplies of irrigation water to the producer are the same as those in the model, which would not necessarily be the case if water charges were imposed.

What this result also demonstrates is that if state interventions into the agricultural sector were eliminated, cropping patterns might not change significantly from what they are at present. Certainly if pricing policy were only changed for a single commodity, the resulting change in cropping pattern would not correspond to those obtained in this permutation of the model. Nevertheless, caveats notwithstanding, this is a significant result. For if the cropping pattern in the border price model resembles existing cropping patterns it is possible to hypothesize that in the event of the elimination of state intervention in the agricultural sector, there may not be significant changes in cropping patterns and hence production, even though the radically different prices imply very different distributions of costs and benefits.

This formulation of the model yields another interesting result. It is commonly argued that significant transfers are occurring out of the Uzbek agricultural sector due to state pricing policies. If this is the case, then this should be reflected in an increase in the value of the objective function for the model using border price values. However, this did not occur. In fact, the value of the objective function using border and shadow price values for farm factors is actually 0.5% less at 520,923, than the formulation using domestic prices, which has a value of 523,298. This result indicates that taxes placed on producers in the form of suppressive output price policies are being offset by subsidies on farm inputs, and indicates that if all taxes and subsidies are eliminated, there would not be a big change in net farm income.

As a brief experiment, an additional permutation of the border price formulation of the model was run which did not require producers to pay the economic price of \$3.33\$/1,000 m^3 of irrigation water. The value of the objective function for this permutation of the model was

639,562 or, 22% greater than the value of the objective function for the initial formulation using domestic prices. A summary of these differences in contained in Table 6. This result

Table 6. Changes in Objective Function Values

	Objective Function Value	Percent Change
Initial Formulation- Domestic Prices	523,298	
2nd Formulation Border Prices- Cost for Water	520,923	- 0.5%
2nd Formulation Border Prices- 'Free' Water	639,562	+ 22%

demonstrates that producers are benefiting from a substantial subsidy by not having to pay for irrigation water. However, if reforms in water policy were also implemented such that it would be necessary for producers to pay for the shadow value of irrigation water, results from this model indicate that the level of farm income would not increase but may actually decrease slightly. In sum, the results from these permutations of the model indicate that if the border and shadow price values for all farm inputs and output are taken into account, it is not possible to conclude that farm income would invariably increase were price distortions in the agriculture sector to be reduced.

In addition to the results obtained for changes in cropping pattern and farm income resulting from contrasts in domestic and border prices, the programming model also yielded a number of interesting results with respect to the supply of irrigation water and its economic value. The first is that changes in water availability have a significant effect on model results. With an abundant supply of water the optimal cropping pattern shifts toward rice. However, at lower levels of water availability the optimal cropping pattern shifts away from rice and toward cotton and other crops. Interestingly, this result conforms neatly to Rybzcynski's theorem which states that if the endowment of a given factor increases, in this case water, then the production of the good that uses this factor more intensely will increase. For the programming model, with greater endowments of water, the production of rice experiences the greatest increase in production. And of course conversely, with decreases in the endowment of water, the production of rice decreases proportionately more than other crops.

This result also demonstrates that despite the fact that rice may have a higher gross margin than cotton and other grains, in the event that there are inadequate supplies of water, (a common occurrence), rice is no longer the optimal crop to plant. In the future it is likely that smaller, not greater, quantities of irrigation water will be available to producers in Karakalpakstan. As such, rice may then continue to be grown in certain areas of the Amu Darya delta in Karakalpakstan where there is adequate water and where rice has been grown for centuries. Nevertheless, as in the discussion concerning horticulture crops, it is likely that a more effective development strategy is to devote scant water resources to crops which are less water consumptive than rice*. Hence, similar to the model results regarding horticultural crops, research into cropping alternatives to rice could prove to be very useful in improving the effective availability of water resources in the region.

The second major result with respect to irrigation water is that the values for the marginal value product of water obtained from the model clearly indicate that a modest charge could be imposed for water without creating incentives for producers to shift their cropping patterns. This is not a surprising result. Without irrigation, agriculture of any sort in Karakalpakstan and Uzbekistan is almost impossible. As a result it is not surprising that the marginal value product of this input has a significantly positive value.

However, while the marginal value product of irrigation water may be positive, it is not clear that changes in water policy in Karakalpakstan could be easily implemented in the short run. Water pricing is likely to be the most efficient policy mechanism by which to achieve more efficient uses of water in Karakalpakstan and Uzbekistan. However, a

* It is worth noting that this position was also confirmed by a rice researcher during a field interview who state that indeed if water were available, then rice could be grown effectively and profitably, but also went on to state that in the event that inadequate water were available, rice would not be an effective crop for producers.

significant amount of additional social research and technical assistance would likely be required before such policy reforms could effectively be implemented.

Conclusions

This study has provided an overview of the contemporary policy environment for agricultural producers in Karakalpakstan and has explored the implications of reforms in agricultural price policy and water management. It appears that a cotton centered growth strategy could be effective over the medium run. If environmental factors related to water quality and availability are taken into consideration, it quickly becomes clear that Karakalpakstan's emphasis on rice production is an artifact of output and input price distortions and does not represent an efficient use of resources. The results for the representative farm demonstrate that if all price distortions are eliminated there may not be a significant change in cropping patterns than those currently in practice. Results also demonstrate that reforms in water policy could be implemented without inducing producers to significantly alter their cropping pattern.

[1] SANIIRI
[2] Micklin, Philip, The Water Management Crisis in Soviet Central Asia", The Carl Beck Paper, University of Pittsburgh Center for Russian and East European Studies, 1991

Glossary of Notation for Model Variables

Variable		Explication
COT	Cotton	Grow 1 hectare of Cotton
SWHT	Spring Wheat	“ “ Spring Wheat
WWHT	Winter Wheat	“ “ Winter Wheat
RIC	Rice	“ “ Rice
ALF	Alfalfa	“ “ Alfalfa
MAZ	Maize	“ “ Maize
MEL1	High Output Price Melons	“ “ Melons
MEL2	Low Output Price Melons	“ “ “
TOM1	High Output Price Melons	“ “ Tomatoes
TOM2	Low Output Price Melons	“ “ “
PAS	Pasture	“ “ Pasture
NIT	Nitrogenous Fertilizer (Ammonium Sulfate)	Cost per ton of nitrogenous fertilizer
PHO	Phosphate Fertilizer (Ammonium Phosphate)	Cost per ton of phosphate fertilizer
KCL	Potassium Fertilizer (Muriate of Potash)	Cost per ton of potassium fertilizer
MNR	Manure	Cost per ton of manure
ALTAI	Primary Tillage	Hourly cost of operation; large tractor
MTZ	Secondary Tillage/ Cultivation	; light tractor
SWATH	Hay Harvest	“ “ ; swather
COMBINE	Combine Harvest	“ “ ; combine harvester
DAYLAB	Day Labor	Cost of Labor per day
DLMAR	Day Labor May	Buy labor in month ofMay
DLMAY	Day Labor March	“ “ March
DLAPR	Day Labor April	“ “ April
DLMAY	Day Labor May	“ “ May
DLJUN	Day Labor June	“ “ June
DLJUL	Day Labor July	“ “ July
DLAUG	Day Labor August	“ “ August
DLSEP	Day Labor September	“ “ September
DLOCT	Day Labor October	“ “ October
WAT	Buy water	Buy 1,000 cubic meters of water (10 vertical centimeters)

Initial Formulation of the Linear Programming Model

OBJECTIVE FUNCTION:

MAX 564COT + 244SWHT + 279WWHT + 856RIC + 218ALF + 279MAZ +
511MEL1 + 256MEL2 + 497TOM1 + 249TOM2 + 20PAS -
110NIT - 172PHO - 103KCL - 4.1MNR -
9.8ALTAI - 3.8MTZ - 7.5SWATH - 11.2COMBINE -
4DAYLAB

SUBJECT TO CONSTRAINTS:

SEASONAL LABOR CONSTRAINTS

ROW 2: LABOR CONSTRAINT TOTAL

93COT + 12SWHT + 63RIC + 10.4ALF + 30MAZ + 9WWHT + 63MEL1 +
63MEL2 + 53TOM1 + 53TOM2 + .8PAS <= 120000

ROW 3: LABOR CONSTRAINT MARCH

1WWHT + 1SWHT + .1PAS <= 12100

ROW 4: LABOR CONSTRAINT APRIL

15COT + 2SWHT + 9RIC + 2ALF + 15MAZ + 2WWHT + 9MEL1 +
9MEL2 + 5TOM1 + 5TOM2 + .1PAS - 1DLAPR <= 12100

ROW 5: LABOR CONSTRAINT MAY

15COT + 2SWHT + 18RIC + 2ALF + 9MAZ + 2WWHT + 9MEL1 + 9MEL2 +
8TOM1 + 8TOM2 + .1PAS - 1DLMAY <= 15125

ROW 6: LABOR CONSTRAINT JUNE

8COT + 1SWHT + 7RIC + 1ALF + 3MAZ + 9MEL1 + 9MEL2 + 6TOM1 +
6TOM2 + .1PAS - 1DLJUN <= 12100

ROW 7: LABOR CONSTRAINT JULY

8COT + 1SWHT + 3RIC + 1ALF + 3MAZ + 9MEL1 + 9MEL2 + 11TOM1 +
11TOM2 + .1PAS - 1DLJUL <= 12100

ROW 8: LABOR CONSTRAINT AUGUST

8COT + 1SWHT + 3RIC + 1ALF + 3MAZ + 9MEL1 + 9MEL2 + 11TOM1 + 11TOM2 + .1PAS - 1DLAUG <= 12100

ROW 9: LABOR CONSTRAINT SEPTEMBER

25COT + 2SWHT + 12RIC + 1.4ALF + 8MAZ + 1WWHT + 9MEL1 + 9MEL2 + 8TOM1 + 8TOM2 + .1PAS - 1DLSEP <= 15125

ROW 10: LABOR CONSTRAINT OCTOBER

14COT + 2SWHT + 11RIC + 2ALF + 9MAZ + 3WWHT + 9MEL1 + 9MEL2 + 4TOM1 + 4TOM2 + .1PAS - 1DLOCT <= 15125

ROW 11-12: BUY LABOR CONSTRAINT

DLAPR + DLMAY + DLJUN + DLJUL + DLAUG + DLSEP + DLOCT - DAYLAB <= 0

DAYLAB <= 12100

WATER CONTRAINTS

ROW 13: WATER CONSTRAINT TOTAL

16COT + 9SWHT + 35RIC + 9ALF + 9WWHT + 17.3MAZ + 14MEL1 + 14MEL2 + 24TOM1 + 24TOM2 <= 50000

ROW 14: WATER CONSTRAINT MARCH

2COT + 2ALF + 1MAZ + 1WWHT <= 6500

ROW 15: WATER CONSTRAINT APRIL

2COT + 2SWHT + 10RIC + 2ALF + 2MAZ + 2MEL1 + 2MEL2 + 2WWHT + 4TOM1 + 4TOM2 <= 8500

ROW 16: WATER CONSTRAINT MAY

2COT + 1SWHT + 4.5RIC + 1ALF + 2.3MAZ + 2MEL1 + 2MEL2 + 2WWHT + 4TOM1 + 4TOM2 <= 8500

ROW 17: WATER CONSTRAINT JUNE

2COT + 2SWHT + 4.5RIC + 1ALF + 2MAZ + 3MEL1 + 3MEL2 + 4TOM1 + 4TOM2 <= 6500

ROW 18: WATER CONSTRAINT JULY

2.5COT + 2SWHT + 6.5RIC + 1ALF + 3MAZ + 3MEL1 + 3MEL2 + 5TOM1 + 5TOM2 <= 6500

ROW 19: WATER CONSTRAINT AUGUST

2.5COT + 1SWHT + 6.5RIC + 1ALF + 3MAZ + 2MEL1 + 2MEL2 + 5TOM1 + 5TOM2 <= 6500

ROW 20: WATER CONSTRAINT SEPTEMBER

1.5COT + 1SWHT + 3RIC + 1ALF + 4MAZ + 2MEL1 + 2MEL2 + 1WWHT + 2TOM1 + 2TOM2 <= 6500

ROW 21: WATER CONSTRAINT OCTOBER

1.5COT + 3WWHT <= 6500

ROW 22-23: LAND CONSTRAINT

COT + SWHT + RIC + ALF + MAZ + MEL1 + MEL2 + TOM1 + TOM2 + PAS <= 1500

WWHT <= 500

FERTILIZER CONSTRAINTS

ROW 24: NITROGEN CONSTRAINT

.42COT + .62RIC + .24SWHT + .24WWHT + .27ALF + .3MAZ + .16MEL1 + .16MEL2 + .11TOM1 + .11TOM2 - NIT <= 0

ROW 25: PHOSPHATE CONSTRAINT

.36COT + .31RIC + .21SWHT + .21WWHT + .21ALF + .2MAZ + .18MEL1 + .18MEL2 - PHO <= 0

ROW 26: POTASSIUM CONSTRAINT

.2COT + .32RIC + .09SWHT + .09WWHT - KCL <= 0

ROW 27: MANURE CONSTRAINT

20COT + 15RIC + 15SWHT + 15WWHT + 10MAZ + .6MEL1 + .6MEL2 + 2.4TOM1 + 2.4TOM2 - MNR <= 0

ROW 28-31: MACHINERY CONSTRAINTS

ROW 28: PRIMARY TILLAGE CONSTRAINT

4COT + 6RIC + 1.5SWHT + 1.5WWHT + 3ALF + 2MAZ + 4MEL1 + 4MEL2 + 2TOM1 + 2TOM2 - ALTAI <= 0

ROW 29: SECONDARY TILLAGE AND CULTIVATION CONSTRAINT

8.5COT + 3RIC + 2.7SWHT+ 2.7WWHT + 2.6ALF + 2.75MAZ + 11MEL1 + 11MEL2 + 7.5TOM1 + 7.5TOM2 - MTZ <= 0

ROW 30: HAY HARVEST CONSTRAINT

6.25ALF - SWATH <= 0

ROW 31: COMBINE HARVESTER CONSTRAINT

2.75RIC + 1.5SWHT + 1.5WWHT + 1.75MAZ - COMBINE <= 0

ROW 32-33: COTTON ALFALFA ROTATION

COT - 1.5ALF <= 0

RIC - 3ALF <= 0

ROW 34-35: MELON1 AND TOMATO1 CONSTRAINT

MEL1 <= 200

TOM1 <= 50

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