ACDI/VOCA - Winrock International
Farmer-to-Farmer Program

Geha Foods
Evaluation of Irrigation for Processed Tomatoes

Consultant Report:
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Volunteer – Irrigation & Water Management

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Declaimer

This report represents the insights of a short term ACDI/VOCA - Winrock sponsored volunteer consultant to the Geha Foods as part of the USAID funded Farmer-to-Farmer program. As with all such consultation there was not enough time to meet with everyone involved or collaborating with the Project. The evaluation, therefore, has to be viewed in terms of the limited visits and interviews made and the information derived from them. This could result in some inaccurate statement, interpretations and excessive extrapolations. None of these are intended, but often can not be avoided. When this has occurred, please accept the consultant's apology and advise him of any erroneous interpretations or information omitted. Also, the ideas and concepts expressed in this report are the author's who is solely responsible for the contents. The opinions are not necessarily those of Geha Food, Winrock, ACDI/VOCA, or USAID.

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List of Acronyms

ACDI/VOCA	American Cooperative Development International/Volunteers in Overseas Cooperative Assistance
CIS	Commonwealth Of Independent States (Former Soviet Union)
DAP	Diammonia Phosphate (18-46-0) Fertilizer
ET	Evapotranspiration
EU	European Union
SIDA	Swedish International Development Agency
USA	United States of American
USAID	United States Agency for International Development

Executive Summary

This consultancy was undertaken at the request of Geha Foods as part of their agriculture services program to promote tomato production by contract farmers. The objective of the consultancy was to evaluate the prospects for improving the irrigation of contract farmers and assure the necessary supply of tomatoes for processing in their tomato processing plant currently under construction. Geha Foods is a private undertaking by a couple from Europe interested in developing a food processing business in Tajikistan for export to the EU and other areas.

The consultancy made an overview review to agriculture in Tajikistan, the irrigation system, how it could be improved, and other issues requested by the client.

The agriculture in Tajikistan remains in a state of transition between the soviet era state and cooperative farms and some ultimate form of economically viable farms under free market conditions. The biggest problem is the need for most of the people living and working on the reconsolidated farms to congenially migrate out to better economic opportunities. Until then it will be necessary to maintain the high labor intensive, but low labor productive production system and corresponding entrenched poverty. This includes excessive labor operating the irrigation system, manually turning water into each furrow. Also, the government is leveraging cotton production as a means of earning revenue, but with a depressed farm gate price. This enhances the entrenched poverty of the farm population.

The irrigation system is a free flow system with water being progressively subdivided all the way to the individual fields of 5 to 20 ha. This results in very limited flows available for application to individual furrows which normally results in over application and inefficient overall irrigation, but not necessarily detrimental to the crops. Furthermore, the control structures appear more improvised than designed with no gates that would allow for rotation of flow between different fields and the ability to irrigate more area at a time. Finally, the irrigation tends to be directly down the slopes with slopes exceeding an estimated 3% which is normally erosive to the soil.

To improve the irrigation there are three choices:

1. Renovate the existing surface irrigation system
2. Convert the system to some type of sprinkler system such as center pivot
3. Convert the system to some drip or micro irrigation system.

Of these the best prospects would be to renovate the existing surface system. This will take some time and have to be done step-by-step with close coordination with the various farm chairmen. They are most likely fairly knowledgeable of what needs to be done to improve the irrigation system, but lack the means to do so, particularly if leveraged into producing cotton at depressed prices. The process would involve:

1. Replacing all the improvised control structures with more permanently designed ones including the use of gates to concentrate enough water into individual fields to allow the faster more efficient irrigation of larger areas.
2. Reshaping the fields with laser grading equipment that will remove the various soil benches in the fields and allow non-critical flow that will not erode the furrows.
3. Developing a water management master plan to rotate the irrigation among the different fields in a manner that will concentrate sufficient water in one field to allow efficient irrigation and return when appropriate.

Geha Foods can provide a facilitating service in this renovation by assisting in the construction and installation of control structures, and providing access to laser grading equipment to smooth the fields.

The possibility of shifting to sprinkler system particularly center pivots is worth considering for suitable fields that can be partitioned into 72 ha square plots. However, sprinkler irrigation for processed tomatoes needs to be done carefully to minimize and infestation of blight or other humidity encouraged diseases. When the fields are suitable and the water supply is adequate center pivots tend to be the most cost effective means of irrigation.

Drip irrigation can be considered but with due caution to the cost benefits relative to other form of irrigation and the complexity of drip in terms of initial cost, frequency of replacement, and operational needs. The only real advantage of drip for processed tomatoes would be the possibility of reducing disease incidents, but the extra cost and sensitivity of the system to be plugged with sediment from the turbid irrigation water, the algae and fungus and crust precipitation could easily off-set the disease control advantage. With the nearly complete canopy of processed tomatoes there would be little water saving benefits. It is really too sophisticated a system for the current agricultural situation in Tajikistan.

The overall need for some agriculture support services facilitated through Geha Foods is a good one and, if organized correctly, should be well appreciated by the farm chairmen, and assure a good continuous supply of produce for processing. Such support services would include provision of hybrid tomato seeds, rent of land grading equipment, rent of transplanters and manufacturing and installing water control structures as currently envisioned, plus other services not yet identified. It is recommended that this be managed as a whole independent subsidiary of the processing plant, with the payment for the support services kept independent of the delivery of produce for processing. Experience in other areas indicated when debt repay is leveraged with the delivery of goods for marketing the farmers will simply avoid repayment by side selling the produce.

Final issues were the use of soil test. These can be a useful means of monitoring long term fertility needs, but should only be done on a field bases and only when the field is being rotated into tomato production.

Introduction

The Assignment

This volunteer consultancy was undertaken at the request of Geha Foods to evaluate alternatives for irrigating processing tomatoes. Geha Foods is a private individual effort by Irena and Helmut Haninger, a couple from Europe, outside Dushanbe, Tajikistan (Fig. 1). While Geha Foods is strictly in the business of processing tomatoes with the potential of processing other foods, they are concerned with the production of the tomatoes and other foods entering the plant to make certain they have a continuous supply of produce to process. It is thus the intentions of Geha Foods to provide some production assistance to the contract producers. At the time of this writing the envisioned assistance is hybrid seed of preferred tomato varieties, as well as irrigation technology including the possible capital costs of renovating the existing on-farm irrigation system, and/or funding the installation of center pivot sprinkler or drip irrigation, if feasible, as well as providing contract mechanization services such as mechanical transplanters for transplanting tomatoes, etc. The organization of these support services in relation to the processing facility has not been fully formulated, and probably can wait until the intended services are more fully developed.

Fig. 1. Geha Foods Tomato Processing Facility under Construction

As the initial part of the agriculture support effort, Geha Foods is currently undertaking variety evaluations of tomato lines from across the globe including local, Indian, European and USA varieties with the expectation of major production beginning next summer. Considering the location and conditions it is really an interesting and diverse set of germ plasma to evaluate. The material from Europe was provided with assistance of SIDA, while the material from the USA was provide via an earlier ACDI/VOCA – Winrock Volunteer. These variety evaluations are laid out more as single replication on-farm demonstrations rather then the more traditional multi-replication field trials normally done for formal variety evaluations. The non-replicated random layout is consistent with previous visits to the CIS and Central Asia evaluating the rice research program in CIS member countries. However, under the circumstances the results should be accurate enough for in-house production decisions. Although, they need to be careful in evaluating those varieties grown in more shaded areas of the various fields.

The Volunteer

The volunteer irrigation consultant is Dick Tinsley. He is an emeritus professor at Colorado State University in the USA, where much of modern USA irrigation technology was and continues to be developed. He is an agronomist with extensive international experience with smallholder subsistence type agriculture throughout Africa and Asia including Pakistan and Afghanistan. His previous involvement in the CIS was an evaluation of rice research in Uzbekistan, Kazakhstan, Ukraine and the Russian Federation in 1994. He has been involved in small scale irrigated agriculture in Egypt, Pakistan, Sri Lanka, Malawi, and Tanzania and related this back to the large scale irrigation of the Eastern Plains of Colorado. While the assignment was specific to evaluating irrigation, other issues were asked and will be addressed briefly. These include mechanization for transplanting and doing that in conjunction with land leveling needs.

Volunteer's Objective: It is Dick's intention to provide as practical an analysis of irrigation as he can based more on observations of what users are doing in the areas he has worked or visited than formal engineering principles. The practical analysis is accompanied as needed by the understanding and explanation as to why the principles have been compromised. Usually, even in smallholder systems, these compromises are highly rational and more a reflection on the limited flexibility of the delivery system they have to operate with then lack of understanding or interest in higher quality water management by the users. The result of all this compromising is the opening comments for the irrigation chapter of his smallholder agriculture book:

> ***More money, time, and effort has been spent by engineers, agronomists, economists and sociologists for less acceptance by users than any other crop management activity, smallholder and large alike.***

Similarly, in response to an internet inquiry to a listserver discussion group on irrigation some years ago seeking detailed crop coefficient information I sent an inquiry asking if the person had an irrigation system that could respond to the detailed information sought. This provoked the following reply from another subscriber:

> "***Measure it with a micrometer, mark it with a grease pencil, and cut it with a chainsaw"***

The impression is that irrigation professionals can measure irrigation perimeters at considerable higher accuracy than most delivery systems will allow their users to take advantage of. While we can generate the data to make irrigation sound like rocket science, it is not. This is even more appropriate for surface irrigation systems and the difficulty to make precision water applications. One important factor that enters most irrigation practices is convenience of operating the irrigation system as this is integrated across the entire farm sharing a common conveyance system as well as into the other farm activities needing urgent attention. This again takes priority over more precise water management, and represents rational and knowledgeable decision making on the part of the users. It is interesting to note that both Colorado State University and the Northern Colorado Water Conservancy District provide detailed on-line climatic information with daily estimates of Evapotranspiration losses primarily for irrigation management, but few farmers actually access the data. Mostly because even though they are aware of what ET is and its potential contribution to irrigation management their systems just don't have the flexibility to effectively use the information and yield impact is really not that substantial. Much of the effort for improved irrigation management in the USA appears more addressing water as an economically valuable and environmental sensitive commodity, than crop yield response.

Agriculture in Tajikistan

Farming Situation

As it was explained and evaluated by the volunteer, post Soviet Tajikistan may require another round of social disruption in its farming and rural communities before stable, economically viable farm units are obtained. What appears to have occurred is, shortly after the Soviet Union dissolved and Tajikistan and other members of the Commonwealth of Independent States (CIS) became independent countries an attempt was made to break-up the large state and cooperative farms by distributing the land, or to be more precisely the right to use the land for beneficial purposes, to the families living on the farms. Families were often provided multiple parcels representing different soils or perennial crop conditions of the State or Cooperative Farm. The individuals were then given lease certificates to this affect. Since when you divide the number of families supported by most state farms by the hectares of the, farm the result is about 1 to 2 hectares per family. This is comparable to typical smallholder subsistence farms throughout developing countries in Africa, Asia, the Middle East and Latin America where smallholders eke a highly impoverished livelihood from the land. Thus, even if you obtained the highest yield of open marketed legitimate crops, it would be difficult for the average farm family to get above the international standard for poverty, usually stated as US$1.00 /capita/day. Farms comparable in size to State and Cooperative farms in the USA can be managed by a father, son and hired mechanic, assisted by some contracted aerial applications, as shown by rice production in Uzbekistan when I visited in 1994. The USA farmers with the limited personnel were actually producing higher yields and higher quality produce than the Uzbekistan farms.

Consolidated Estate Style Management

In fully irrigated Tajikistan, unless the irrigation system was rapidly modified to accommodate the small parcels with individual access to water, the simple allocation of parcels of land to the families of the previous State Farm, would require either the parcels be very long and narrow going from canal to drain so that everyone had individual access to water as is done in Central Luzon Philippines with fields being 1 km by 10 m. (Fig. 2) or down stream farmers will have to irrigate from an upstream farmers tail water, or have water transit through a upstream field. This would be virtually unmanageable from the irrigation perspective and thus the total subdivision of land to member families would quickly become unfeasible. This appears to have happened and after a few years of attempting independent farming the farmers agreed to return to consolidated management or estate mode management. This again needs to be looked at with caution and be fully cognizant of the Gizeria Scheme in Sudan. It is a 600,000 ha irrigation scheme the British built for mandatory cotton production approximately a hundred years ago at the confluence of the Blue and White Niles just outside Khartoum. Imposing consolidated estate style management operating across individual designated holdings they created the biggest irrigated agriculture development disaster in history, both in terms of irrigation management and the rest of cotton production.

Fig. 2. Aerial View of Central Luzon Philippines where farms can be 1 km x 10 m to allow individual access to both the irrigation canal and drain.

Returning to Tajikistan, the return to consolidated management may still represent a pro-rated physical resource for each family too small to be economically viable. Thus, even with high yields of high valued crops, it will be difficult to generate enough returns for the farmer/shareholder/laborers to rise above the poverty level. It would also be necessary to factor in the high overhead costs of consolidated estate management. Historically, large farms have lower profit margins per land unit, but because of large acreage the largest total profit than compared small scale operations. Thus, the reconsolidated farms in Tajikistan may represent the limited large farm profit margin pro-rated over a smallholder physical resource base, and the potential income from the reconsolidated farms could be less that from individually managed farms if provided with good irrigation access. It would be even more difficult if leveraged into producing a crop with depressed price control as mentioned for cotton.

Economic Viability

Thus, in order to obtain economically viable farms without having the farm population entrapped in poverty similar to the feudal serfs in pre-revolutionary Russia, it will be necessary for a substantial number or even the majority of the families to give up and leave the farm. This will reduce the labor pool and force more efficient farming activities, increase the productivity to the remaining labor pool and justify the higher income needed for poverty alleviation. This may actually be taking place at present with reported large numbers of men going to Russia as guest workers similar to what is occurring in other countries such as Sri Lanka, Pakistan, and Philippine guest workers going to the Persian Gulf States, African guest workers to South Africa, Turkish and North African guest workers to Europe and Mexicans to the USA.

Migration from the reconsolidated farms is going to be socially disruptive as all economic change is, and that will be difficult to avoid. However, it will be better to draw people out of the farms with substantial industrial growth generating jobs such as the Geha Food processing facility. Additional agro-industrial facilities should be encouraged and donor institutions provide some supporting finances and the government incentives. The alternative would be to have the surplus personnel effectively expelled as may currently be happening, with the marginal wages currently afforded by the farm management. The example mentioned is having farm workers weed cotton in exchange for a delayed in-kind payment of the residual cotton stalks after harvest which they can use for fuel in their homes, but not consume. Meanwhile, they grow increasingly in debt and may have to forfeit there lease certificates to cover their debt. The result would be in consolidation of ownership, possibly into the various farm chairmen, and displacement of shareholder/laborers. The consolidation of ownership will improve the overall agriculture efficiency, but could cause severe problems in the cities like Dushanbe if displaced farm families migrate to the cities looking for any opportunity. Meanwhile, the farm shareholder/laborers manage to survive on their private plots which were intended as supplemental income instead of primary income. The result is a very difficult, arduous life style, which can only result in reduced life expediency (Fig. 3).

Fig. 3. Small Child pressed to work bringing fodder home as part of arduous lifestyle of rural Tajikistan.

Until such time as an out migration from the farms can congenial be managed, it will be very difficult to modify the labor intensive farming system, including the manually managed furrows of the irrigation system. Labor is viewed as job security, even when providing an impoverished livelihood. The labor intensity appears on par with most highly subsistent developing countries and levels not seen in the USA or Europe for 70 years or more, as noted by the four stage wheat harvest that involves (Fig. 4):

- cutting & windrowing with a combine,
- stacking,
- threshing and winnowing, and
- hauling the crop from the field.

Fig. 4. Wheat Cut, Windrowed, and stacked waiting to be threshed by portable thresher. Extremely labor intensive, but not necessarily labor productive and most likely resulting in deeply entrenched poverty.

This instead of a single pass with a combine doing all the above and off to the grain silos with any drying being done by forced air units in the silos.

Cotton Priority

As explained to the consultant the government tends to have a policy of promoting cotton as a means of generating government income based in part on a depressed farm price and marketing deseeded cotton on the world market at substantial profit for the government. In promoting cotton production in what could easily be a non-economic production system the government representatives are obliged to obtain regional quotes with their jobs on the line for failure to meet it. They then take advantage of the escape clause in the land lease certificates stating the land is available as long as put to beneficial use, which could be defined solely as producing cotton. This effectively leverages cotton production against the economic returns and is very analogous to cotton production in Egypt, with enforced acreage allocations and potentially generates a similar level of resentment from the farm community, with the accompanying diversion of fertilizer and other inputs to rice and vegetables such as tomatoes. Some of what has been described to me reminds me of Frank Norris's book *The Octopus* that describes how big business, particularly the railroads, leveraged the agriculture in California in the early 1900's to their greedy advantage and `of the farmers.

Current Irrigation System

Overview Analysis

When an outside consultant reviews an irrigation system or any agriculture activity during a brief consultancy and sees what appears at substantial variance to what he is expecting and what are the normal applications of basic irrigation principles to his reference environment, it is essential to consider that appearances can be deceiving. The questions that have to be carefully asked are:

a. Does what is being observed represent a lack of knowledge on the part of the farm management of sound irrigation principles, or
b. Does it represent the knowledge but lack of concern for good water management, or
c. Does it represent the knowledge and concern, but the lacks of means to better manage the irrigation system, etc.

Too often the interpretation is either “a” or “b”, lack of knowledge or lack of concern. However, more often than not, in this consultant experience, it has been “c” lack of means, and the emphasis on “a” and “b” at the expense of “c” has been major reason for the limited effectiveness of total agriculture development effort over the past 40 years. How you approach improving the irrigation system or other agriculture activity varies tremendously depending on which of these choices is assumed and which is actually correct. In the first two cases the need is to emphasize knowledge, education and motivation, while in the latest case it is facilitation and enhancing the resources available to the farmers to do what they already knows needs to be done. Mistaking “a” and “b” for “c” can not only result in an ineffective effort, but can be somewhat antagonistic to sensitive recipients as it implies considerably less competence than they may actually posses.

When the farm chairmen in the last field visit could accurately tell the elevation drop down the furrows and acknowledge the importance of leveling, but claim that it has not been done since Soviet time, I think “**lack of means**” could be the major problem. Certainly, if he is leveraged to produce cotton with uneconomic returns, the lack of means to fully maintain the on-farm irrigation system is very real. It has to be a legitimate second priority to wages for the farm families. If this is the case, Geha Foods can provide some valued assistance to the farms by working with the various chairmen and implementing irrigation improvements as fields are rotated into tomato production, and mostly following the desires of the farm chairman for what he sees as needing to be done. From the political perspective of obtaining the cooperation needed for tomato production, it is really the only option.

Brief Description Irrigation in Tajikistan

Field Applications: The current irrigation system in Tajikistan is a surface system that appears developed primarily for large State Farms, with their excessive labor supply. It thus appears more like the systems I have seen serving smallholder communities than those serving large farms. This has resulted in the water flows that appear subdivided to the extent the water can be manually shifted to individual furrows or small groups of furrows (Fig. 5), rather then large 20 ha surface irrigation sets common in Eastern Colorado. Such limited flows result in substantial conveyance losses in the system most of which will leach to the water table and eventually return to the rivers. Also, the irrigation furrows tend to run directly down the slopes instead of along the contour with slopes of up to an estimated 3% (Fig. 6). This is too steep of non-critical (laminar) flow resulting in turbulent flow and noticeable erosion in the furrows, some of it approaching 30 cm of erosive cut. To some extent the erosion is minimized by allowing very low flows to enter the furrow, perhaps as low as 0.25 l/s instead of the 1 l/s or more usually needed to push a wetting front expediently to the end of a furrow. Furthermore, the furrows are not uniform in grade and will have one or two benches down the furrow that will slow the flow, deposit some suspended sediment, and possibly breech between furrows, before continuing to the end of the furrow (Fig. 7).

The actual flows into the individual furrows are often insufficient to reach the end and the irrigation physically stalls, preventing the lower end from receiving any water. Irrigation stalls occur because as water flows down a furrow or basin the wetted surface continually increases as does the rate of water infiltration (Fig. 7). If the rate of infiltration exceeds the rate water enters the furrow no further advance is possible and the irrigation stalls. It also results in increasing the opportunity time for water to infiltrate and thus increases the application rate at least for those areas receiving water. Increasing the application rate will only result in more water leaching to the water table, possible carrying some Nitrate-N. It will have only minimum impact on the overall crop response and little short term economic or environmental impact unless water is expensive, and/or water logging conditions are produced at some point prior to returning to the river. Even so, the total length of reaches are between 100 and 200 meters compared with the 800 meters standard for Eastern Colorado, and the 1600 meters (1 mile) reaches used in the Boswell Ranch of California.

Fig. 5. With limited water only a few furrows could be irrigated at any one time. Note pieces of plastic at each furrow entrance to reduce erosion.

Fig. 6. Irrigation going directly down slopes of 3% with high erosion potential. Also, field has one or two benches in them that further hinder flow.

Fig. 7. Very limited discharge available for irrigation furrow, resulting in excessive water applied and frequent irrigation stalling. Also note the bench in the middle of the field that will slow the flow before proceeding to the end of the furrow.

Water Supply: The overall supply of irrigation water in the country seems adequate. The water source is primarily winter snowmelt with little if any supplemental summer rains (Fig. 8). Normally, this results in a snowmelt hydrograph that peaks in late spring and early summer, such as May and June in the northern hemisphere, and rapidly declines as summer advances, until the base stream flow is obtained in fall (Fig. 9). However, it appears even with the summer decline there is ample water for irrigation, a situation that is relatively rare, unless the late summer irrigations after the normal decline in the snowmelt hydrograph are based on return flow from early irrigations in the upper part of the system. In this case the inefficiency of the system is basically the storage system and improving irrigation efficiency in the upper reaches could have adverse impact on down stream users. The basic physics is that matter can not be created or destroyed and the surplus water applied has to go some place. Using the irrigation system to temporarily store water and buffer the hydrograph is fairly common. Diverting large volumes of water for rice production in the Sacramento Valley of California even outs the flow of water that has to be pumped into the Central Valley Project and prevents the pumps from becoming overwhelmed with the spring runoff. Similarly, the annual diversions of the Platte River in Colorado are more than twice the annual flow, with the river totally dried into the irrigation system at least four times between Denver and the Nebraska state line. The down stream users are dependent upon the 70 l/s/km return flow. When farmers near the mountains started converting to center pivots and reducing the return flow it created some major problems for down stream users.

The only storage facility in Tajikistan is a hydroelectric dam. While the releases for the dam are determined by power needs, the discharge goes into the irrigation system and effectively buffers the hydrograph of its command area and assures the supply of water throughout the growing season. Given the overall supply of water and normal snowmelt hydrograph, it should be possible to develop more storage structures and expand the irrigated area, if there are suitable gravity accessible arable lands. It would also increase the electrical power supply for the country or export. This would again be analogous to Colorado where virtually all snowmelt is stored for use in the irrigation system as well as progressively serving the urban expansion from Denver. Using waste water for irrigation of agriculture crops effectively improves the quality of the return flow. The entire system in Tajikistan is government owned and managed.

Fig. 8. Snow melt coming from below the remaining snow pack in a branch of the Varzob Gorge, near the Ushtur Tunnel and headed for the irrigation system.

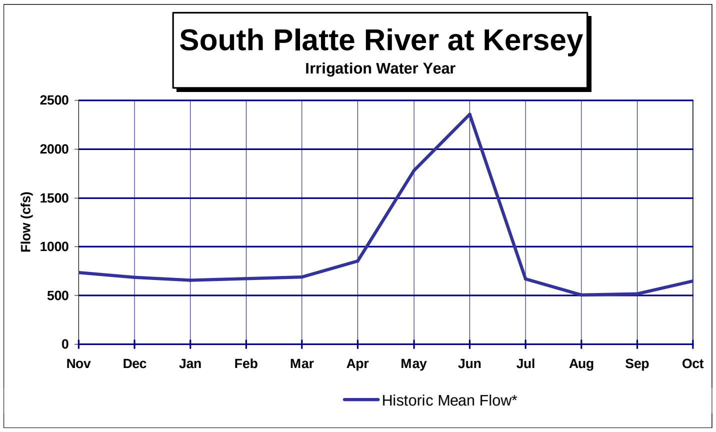

Fig. 9. Typical river hydrograph for snowmelt with peak flows in May and June and rapidly declining flows in July, August and September. Example is from Platte River in Colorado.

Field Delivery: The water appears to flow continuously through the canal system without any major rotations imposed at any level. This extends to each individual field so that all fields are irrigating continuously, but with a very limited supply of water, too limited for effective applications. There appear to have been control check structures for proportioning the water into the different canals as well as drop structures to maintain non-critical laminar flow, but there did not appear to be any control gates within the farms. Also there appears to be some staff gages set in the canal at point with a clear cross section and thus good points to measure the flow. The expectation is that these were more for planning purposes than operation control as well as determining the water duty for the different crops. Many of these structures appear more improvised than designed, with many needing some maintenance attention that varies from simply removing lodged debris to full reconstruction to reestablish the design height and cross section (Fig. 10 & 11). Several have been filled with some form of riprap to approximate the intended control, but with substantial leakage.

At the field level the controls are even less apparent with water flowing through cuts in the canal banks and wander over several meters of access land to reach the head ditch (Fig. 12). Usually concrete or other non-erosive control structures are beneficial all the way to the head ditch to assure uniform supply of water to the fields. Renovating and expanding the control structures on-farm would reduce the overall leakage and assure more water is available for irrigating each furrow. This in turn would allow the furrow and fields to be irrigated more quickly applying less total water that would reduce the water leaching to the groundwater.

Fig. 10. Improvised check/drop structure made of some riprap used to attempt to control canal water.

Fig. 11. A similar improvised control structure to divert water, but with considerable leaking occurring.

Fig. 12. Water coming from a cut into the canal down a bank to get to the very small head ditch.

The head ditches are very small and not suitable for anything but bank cuts to bring water to the individual furrows, which often have small plastic or canvas covers to reduce erosion of the furrow inlet (Fig. 13). While there is enough potential head for the head ditches to be large enough to accommodate siphon tubes, gated pipes or gated canals, none appear adapted for this and would really only be appropriate if this equipment was available.

Fig. 13. Small head ditch with plastic drop structures to assist water getting to the furrows.

<u>Canal Management</u>: There are informal reports that some irrigation managers may be using their authority to restrict the flow to different areas in order to obtain some informal income by withholding water until an acceptable incentive is received. If this is the case, it can fully destroy any effort at improved irrigation scheduling and related water management. The only logical recourse for the farmers is to irrigate every time there is water in the canal as the opportunity present itself to minimize any water stress. With irrigation the penalties for under irrigating and stressing the crop are substantially greater then the penalties for over irrigating. Please don't blame the farmers for logical choices with an unreliable delivery system.

Water Charges: There is an effort to charge farmers for use of irrigation water. This is proclaimed as a volume charge but no water is actually measured. Instead it would be more accurately called an area by crop charge, and assumes the crop only receives the estimated water duty for that crop. Without actually measuring the water, an estimated volume charge is not effective in reducing excess water use, if that is part of the purpose. Trying to manage a true measured volume charge can tremendously increase the administrative cost and become a major financial burden to the farmers, particularly smallholders. However, in Tajikistan collections are difficult, and if you are making informal payments to secure water, you are reluctant to make formal payments. Unless, of course, the opposite is happening, and the informal payment is *in lieu* of assessed charges. The end result is no funds for necessary maintenance work on the main diversion and canal system. Since the government appears to be making substantial profit from cotton sales, a portion of which represents a depressed farm gate cotton price, the depressed cotton prices could be viewed as a rural tax, and part of the revenue gained be allocated for irrigation infrastructure maintenance, and in reality this is a easy form of taxation or water user fees to collect.

Improving Irrigation for Processing Tomatoes, etc.

Overview

Before reviewing the different possibilities for improving the irrigation system for processed tomatoes in conjunction with other crops, it might be desirable to review a couple points in advance.

Multiple Crops Involved: First, it appears the tomatoes will not be produced alone but most likely produced along side of Cotton, with most of the public sector support services focused on cotton. Tomato production could actually benefit from the excessive government emphasis on cotton with depressed returns, as inputs usually get favorable diverted from the less economic to the more economic crop. Thus any renovations to the irrigation system at the farm level will have to consider both crops and the probability of rotating between them, as well as other crops like winter wheat, potatoes, vegetables, etc. This rotation with other crops might be important in controlling some of the soil borne diseases of tomatoes such as late blight. Renovating the irrigation system for both tomatoes and cotton should not be a major problem as both are furrow irrigated with tomatoes usually grown on beds approximately twice the width of cotton furrows. Thus most likely it would be possible to grow cotton on tomato beds using two rows per bed instead of one.

Evapotranspiration Energy: Also, the other problem is that the water requirements are reasonable similar for all crops during the balk of the growing season. This is because the water requirements of different crops are more an external climatic factor, than an individual plant factor. This is really basic physics as transpiration represents a change in state of water from the liquid to vapor state. This is referred to as the *latent heat of evaporation* and requires some 536 cal/cc of water. This energy is not available from within the plant. It really comes from direct solar radiation and consumes most of the solar radiation reaching the plant. The evaporation has a cooling effect and prevents the plant from overheating. Since all crops growing in proximity to each other such as cotton and tomatoes receive the same amount of solar radiation and are of similar color they consume virtually the same for photosynthesis energy, usually only about 3%, with the rest going to Evapotranspiration. There may be some different responses to water at specific stages of individual crops growth cycle such as shutting off the water to cotton to assist in flower setting and boll formation, or stressing processing tomatoes for better solid content before harvest. However, during most of the growing season the difference in water requirement would be less than most systems can effectively respond to.

Plant Water Extraction: There may also be some differences in the frequency of irrigation for different crops reflecting difference in rooting pattern and ability to uptake water. Thus tomatoes may have to be irrigated more frequently than cotton, which is considered to have deeper roots and can extract more water from the soil than tomatoes. This would mostly be a concern with surface irrigation in which the typical application exceeds the available soil water storage capacity making over irrigation necessary to avoid stressing the plant. The problem virtually disappears with sprinkler and drip systems, which are more likely struggling to keep up with ET rates. The extra water required by tomatoes for surface irrigation would then be a function of inefficiency of the surface irrigation system to deliver the smaller amount of water at more frequent intervals than a difference in actual water requirements as reflected in ET rates. It would also fully compromise a detailed irrigation scheduling system based on ET rates and the need to integrate irrigation throughout a farm sharing a common primary delivery system, and not just one field of primary concern.

Also, since most irrigation modification and improvements should last more than one year, they will by necessity be involved in more than one crop and it would be impractical to consider only tomatoes in whatever crop sequence is intended.

Water Requirements

The actual water requirements for irrigation purposes would be based on the maximum ET rates. Using a high temperature of 45˚C and relative humidity of 25% the computed potential ET by the Penman-Monteith formula for Dushanbe is 11 mm or more per day (Appendix). That converts to 1.3 l/sec/ha or 390 l/sec for a 300 ha farm, assuming 100% application efficiency. This then has to be divided by the estimated application efficiency to obtain the actual flow rate needed. For example, for a surface irrigation system at 70% efficiency the inflow would have to be 390 / 0.7 = 557 l/sec continuously for the season. If converting to low pressure sprinkler or drip system with 95% efficiency the water needs would be 390 / .95 = 410 l/s.

Crop Response to Irrigation

Most crops including tomatoes can be expected to show an agronomic response to water up to the ET rate. Above this there would be limited response as there is no longer a need to cool the plant. For this reason the penalties for under-irrigation and stressing the plant are substantial while the penalties for over irrigation are almost negligible, at least in well drained soil such as seen in the field visits (Fig. 14). The only thing that over irrigation does, on well drained soils, is to allow water to leach to the groundwater taking some nitrate fertilizer and removing any salts that are accumulating. If this water makes it way back to the main river in the areas it becomes return flow and can be reallocated for irrigation and, since there are no storage structures, down stream users may actually be highly dependent on this return flow to meet their irrigation needs. In poorly drained soils, it can become a major problem with water ponding in the fields long enough for anaerobic conditions to occur and crops to suffocate as well as develop seepage areas and salt accumulations, etc. However, the farms visited appeared to have sufficient deep drainage canals so it would not be a major problem for the contract farmers. Typically it takes about 24 hours of ponded water for anaerobic conditions to damage a crop. Tomatoes are one of the more sensitive crops to wet feet.

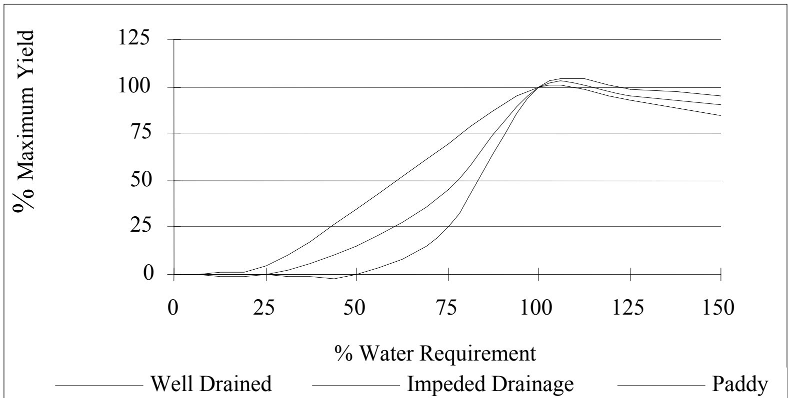

Fig. 14. Schematic crop production function to applied water

Irrigation Promotions: It is interesting to note that most of the irrigation efficiency efforts in the USA are not driven by agronomic yield increases, but by water as an economically valuable and environmentally sensitive commodity. In the USA, with our very complex, privately owned system of water rights, we have by necessity become obsessed with measuring water. Water rights have highly paid lawyers specializing in water law and courts dedicated to water rights litigation. Since we obtain water on a volume basis any water saving has a direct economic return in terms of reduced production cost, and opportunity to "rent" unused water to other users. It is also interesting that much of the shift away from siphon tubes to gated pipe and center pivot irrigation system was driven more by increased labor cost then need to conserve water. The water saving was a nice by-product. For over a century Colorado irrigated at about 30% efficiency with no apparent detrimental impact on crop yield or the environment and many people filing water rights on the tail water of other users.

In Tajikistan with what appears an ample water supply and not encumbered with the complex water rights laws of the USA, the need to keep accurate account of water is greatly diminished. With this will come less concern for irrigation efficiency. Thus, the emphasis on irrigation management will rightly be making certain the crops ET needs are met, and little more. Over irrigation will not be a major concern and one that the drainage canals should readily handle. This limited need for highly sophisticated water accounting needs to be carefully taken into consideration in evaluating how to assist farmers in improving their irrigation for producing processing tomatoes and make certain there is a solid economic return to the efforts, or a long term positive environment impact, and sustainable economic return.

Options for Improving Irrigation

What are the options to improve irrigation management on tomatoes and other crops produced in rotation with the tomatoes? Most likely they will be limited to:

- Renovating the existing surface irrigation system
- Shifting from surface to some form of sprinkler such as center pivot
- Shifting to some form of drip, micro irrigation.

Renovating the Existing Surface Irrigation Scheme

Surface Irrigation

Perhaps the easiest means of improving the irrigation for the contract farms would be to work closely with the respective farm chairmen to renovate the existing surface irrigation system. The two key aspects of this are consolidating the flow of water to fields so they can irrigate faster and more efficiently and grading the fields so water can easily pass down the furrows without causing erosion or ponding water on the land benches. This would bring the irrigation system similar to the remaining surface irrigation in Eastern Colorado. The land, topography, and field sizes appear appropriate in most cases. It has to be recognized that surface irrigation is the oldest and simplest form of irrigation and, in the processing tomato growing center in California surface irrigation remains the primary means of irrigating processing tomatoes. However, this is shifting to drip systems in response to increased costs for surface irrigation water. Surface irrigation normally requires no water treatment to remove sediment, but could benefit from the removal of floating debris. Some concern has been expressed about diseases such as late blight being spread through an irrigation system. While I can not deny this, neither can I confirm it. I will have to wait until I return to Colorado and discuss this with the plant pathologist across the hall from my office. I am somewhat skeptical of this happening or being a major concern based on the long standing California experience of continuous tomatoes with surface irrigation. I would expect it would also be a problem with sprinkler and possibly drip as fungus spores most likely are small enough to easily go through any sprinkler head as well as both the sand filters and emitters of a drip system. My colleague has since confirmed the possibility of the problem of fungus spores being transported by irrigation water but considered it to be minor and surface irrigation of tomatoes remained his preference. He also acknowledged that fungus spores could easily pass through sprinkler heads and drip filters.

Conceptual Ideal

From a conceptual idealist approach to surface irrigation the best example would be Eastern Plains of Colorado. Here the land is surveyed into sections one mile square (1.6 km). Farmers then divide their land into 14 fields of approximately 20 ha each. Each field is irrigated as one unit from a head ditch for 12 hours then rotated to the next field. The water is on continuously and it takes a week to make a full rotation. This is kept up from April to October regardless of any rain or other climatic activities that would affect the ET needs of the crop. All the fields are precision graded so the water flowing down the furrows on a non-erosive grade of 1% or less with a minimum discharge of 1 l/s/furrow. The discharge into the farm is approximately 450 l/s. The irrigation runs are approximately 800 m. The total application is in the order of 10 to 12 cm against a weekly ET rate of 7 to 8 cm. Farmers have been irrigating in this manner for approximately 140 years. Most of the time the water went from head ditch to furrow with siphon tubes, but this has more recently been shifted to gated pipe in response to declining farm labor for setting the siphon tubes (Fig. 15). The basic principle of this irrigation is convenience including not having to contact the ditch company every few days to turn the water on or off, and the corresponding conveyance losses associated with draining and refilling the canals. Once in place it is really very difficult to make any adjustments to accommodate rainfall or other shifts in plant water needs and no need to collect daily ET estimates.

Fig. 15. Gated pipe used for surface irrigation in USA, with a discharge exceeding 1 l/s/furrow.

Adopting to Tajikistan

Adopting this somewhat ideal example of surface irrigation to Tajikistan will take some effort and will most likely only be done in small stages with close coordination with the farm chairmen, primarily as fields are rotated into processing tomato production. The assumption here is that the farm chairmen have a reasonably good understanding of the needs for improved irrigation but don't have the financial means for doing so. Thus Geha is providing the means with some effective business plan to recover the costs from the farm. These improvements would blend well with the agriculture support services concept being developed by Geha Foods. There are probably three things that can be gradually improved.

1. Availability of water at the field
2. Field application of water
3. Overall farm water management

Water Availability: Increasing the availability of water to fields will allow for more rapid and efficient water applications. This could be done mostly by improving the canal control structures to better concentrate water at the fields being irrigated and eliminate much of the leakage around the different structures as previously shown in Fig. 10, 11 & 12. It would mostly involve removing the improvised control structures and replacing them with true reinforced concrete or other permanent materials that provide reasonably water tight seals and easily operated gates. Most likely there are only a limited number of sizes of control structures needed and these can be prefabricated of reinforced concrete at reasonable costs at the factory, transferred to the farms, and installed as needed. There are really only two types of structure involved. One is simple drop structures that safely drop the water from one level to the nexts, and the other is diversion structures that contain some form of gate that can be opened or closed depending on where the water is needed. The simplest gate would be a simple slide gate that fits into grooves in the control structure and can be lowered to raise the water level and allow water to enter a field or canal and removed to allow water to move straight through to the next reach. There are many different styles for constructing these two structures, all of equal value, and you can proceed to develop on your own. The simplest is usually the best. I will attempt to get some illustrations when I return to Colorado.

Field Application of Water: Can best be improved by first reshaping the land. Apparently, this was done during Soviet times, most likely using cumbersome land planes, but has not been done since. The land shaping now is best done with laser leveling equipment. With such equipment one laser source can usually control 3 or 4 scrapers spread over 50 ha or more (Fig. 16). The computer controls in the standard laser targets are capable of making an initial survey of the field, and then proceed to move the necessary soil to have the field fully graded. Typically, a 20 ha field can be laser graded in one day, although the first time it might take an extra day because of larger amounts of material to move. It also might take longer if smaller tractors are used consistent with the need for pulling transplanters. The laser source can be set at dead level or on any pre-determined slope, and will grade the field to that standard with an accuracy of ± 2 cm. The ultimate objective is to get a smooth field with an irrigation run of 1% or less. However, an intermittent objective might be to mostly get rid of the benches in the middle of the fields so water can flow smoothly from top to bottom of the furrows. Eventually, it might be desirable to change the direction of the furrows so they are running more parallel to the slope instead of down the slope.

Fig. 16. Laser guided scraper with laser target mounted on scraper automatically controlled by the tractors hydraulic system.

The laser equipment including source, and target equipped would be a reasonable set of equipment for Geha Food agriculture support service to obtain and make available on rent bases, with possibility of some form of credit being available. I checked the price with some local suppliers and they mentioned the source would run about $4000, while the targets when fully linked to the tractor hydraulics for automatic control would be $25,000 per unit and excluding the cost of the scraper. That is somewhat more than I expected.

Once the water is more concentrated for easier irrigation and the fields have been graded, it would be possible to consider some more controlled means of assuring a uniform application of water to each furrow instead of the current cut from the head ditch with a targeted discharge of 1 l/s/furrow. In the USA this was historically done with siphon tubes that have recently given way to gated pipe. In Tajikistan it might be possible to make adaptation of some materials that appear readily available. This would be the trapezoidal pre-cast concrete canal material that is used extensively around the country including some of the irrigation canals to move surface water around (Fig. 17). If these could be lined up on the dead level, simple gated outlet structures could be cut near the top at intervals equal to furrow widths. Then with simple check structures in the canals, it would be possible to raise the water level in the concrete gated canal above the ports and allow water to enter each furrow. Similarly, removing the check structure would allow water to drop below the ports and down to another reach. If dead level and with reaches of appropriate size, a uniform flow of water would enter each furrow and proceed uniformly down the furrows and reach the end at nearly the same time. The target application should be 1 l/s/furrow. Again Geha Foods agriculture support service could be of assistance to the farms by providing credit and assisting in the installation of the gated canals.

Fig. 17. Prefabricated canals commonly used in Tajikistan for moving surface water that have the potential to be used for gated head ditches by installing ports near the top of the section. The example is approximately 60 cm across the top as shown by the individual hand being at 1 m.

Overall Water Management: The overall water management of the farms will be somewhat more difficult to obtain as it has to integrate the needs of all the different crops and fields into a master plan of some kind that may need to be adjusted on an annual basis depending on the revolving mix of crops. It would be nice if the farm could be blocked into 14 nearly uniform field plots and rotate the water on a weekly basis as described in the conceptual example from Colorado. However, an established surface irrigation system has well established canals and drains that can not be easily changed. Thus any irrigation plan has to accept the land units as they are and block them as best they can for easy within farm rotations.

<u>Collaboration With Farm Chairmen</u>: The ability to implement any improved surface irrigation system for processed tomato production in conjunction with cotton and other crops can only be done in close cooperation with the farm chairmen, and following their suggestions and recommendations on how to proceed. However, it must be recognized and fully appreciated that the chairmen has to be concerned with the entire farm and not just the tomatoes. His overall objective then has to be maximizing the farms returns to all farm enterprises. This in turn may mean neither tomato, cotton nor other crops receive the recommended best management practices. This is in really optimal farm management. Included in this is any leveraging he will be subject to by the government for cotton production. Geha Foods and their agriculture support services can only serve as a facilitating organization to assist with some of the equipment, supplies and materials, etc. Most likely this will require a legal enforceable contract between Geha Foods and the individual farms, and this should be independent of any contracts on tomato production for the processing plant.

However, in assisting farm chairmen to better understand the potential for improved surface irrigation it might be desirable to provide some travel opportunities to the USA, European, or perhaps Australian areas heavily involved in large scale surface irrigation. This will allow the farm chairmen to better visualize how surface irrigation in Tajikistan can be improved. It is really difficult to conceptualize this without some study tour activities.

<u>Opportunity Time</u>: A major problem in implementing irrigation improvements is the opportunity for doing the work. While it may be possible to install prefabricated control structures with minimal interruption of the water flow, grading land can only be done between crops. Typically, any given field may be totally fallow for as little as 2 weeks between successive crops. However, since different fields will become available at different times the total opportunity time to renovate fields could extend to 6 or 8 weeks per crop conversion period. This is actually a reasonable amount of time, but will require some serious coordination between farm management and Geha Foods.

Shifting to Sprinkler Irrigation

Center Pivots

Another form of irrigation for processed tomatoes to consider is some form of sprinkler irrigation of which the most widely accepted is the center pivot. This is a self propelled system that can irrigate 50 ha from a single water source. This system was invented about 60 years ago and has become increasingly popular, with many farmers in eastern Colorado shifting from surface systems to center pivot in response to the continued decline in farm labor. The center pivot systems can easily be seen in aerial photos or satellite images as a series of circles sometime clustered to totally fill a photo or image (Fig. 18).

The basic principle is to have a centrally located water source that can be a well or underground pipe from a canal to the pivot. Then a single pipe beam is extended some 400 meters supported by a series of A-frame towers, usually 7 or 8 towers (Fig. 19). The unit then slowly and continuously revolves subscribing a full circle, normally once every 24 hours. The nozzle size is adjusted along the boom with the smallest nozzles near the center and largest at the end towers to assure uniform application.

Fig. 18. Aerial View of Center Pivot Irrigation in San Luis Valley of Colorado. Each circle represents 50 irrigated ha. in a 72 ha square.

Fig. 19. Center Pivot Irrigation unit covering 50 ha in 24 hours.

Originally, center pivots were high pressure units with overhead impact sprinkler that generated considerable drift particularly on the windy plains and thus not very efficient. Over the last 20 years they have mostly been retrofitted or replaced with low pressure drop nozzles that are cheaper to operate and eliminate the drift so now most have an application efficiency of up to 95%. They are unable to reach the corners so a 72 ha square of land may have only 50 ha of net irrigated area. However, most farmers have taken advantage of this to move their homes and farm building to the corners so the net irrigated area loss is comparable to the loss for conveying canals and drains in a surface irrigation system. In addition when canal water is used, usually the farmer will have a small retaining pond in one of the corners to allow the sand to settle and any surface debris to be screened off and buffer any interruptions in supply. The latter may be a concern with canal water in Tajikistan.

Chemigation

Center pivots have also become a convenient means for applying N fertilizer as well as crop protection chemicals for insect and fungus control. The latter could be of particular concern with processed tomatoes.

Other Self Propelled Systems

There are other moveable sprinkler systems but most are higher pressure thus more expensive to operate and often have problems with keeping the water supply up with the moving head unit. The most common method is some kind of hose drag system. The alternative is jumping from hydrant to hydrant. However, this tremendously increases the mechanical complexity and thus opportunity for breakdowns. Most linear move units with hydrant couplings I am familiar with were given up years ago as to time consuming and expensive to maintain. My department has one for research purposes, but it relies on a hose drag system, and should not be considered on par with production units.

Disease Prospects

Concern was expressed that sprinkler irrigation was unsuitable for processed tomatoes because of humidity sensitive diseases such a blight. Inquiries to Valmont, the original manufacture of center pivots, acknowledge a concern, but one that was surmountable. They mentioned substantial processed tomato acreage under center pivot in South America providing tomato paste to Italy, plus an article from the USA where processing tomatoes were successfully grown under center pivot. However, a reply for Heinz seed reinforced the concern with expression of reservations using center pivots for tomato. Since Valmont is promoting Center Pivots and Heinz is promoting tomatoes, I would consider Heinz the more objective source on this issue (See Appendix for Correspondence and Article). My guess is that those using Center Pivot for tomatoes are doing so with substantial fungicide being injected into the center pivot system. Certainly if center pivots are introduced, it will be necessary to select varieties with the most durable multi-gene resistance to blight and other diseases.

Representation in Central Asia

Valmont does have representation in the region working from Azerbaijan and estimates it would cost roughly $1000 per hectare to install a basic unit. These costs could increase up to 20% depending on the accessories you wish to consider, and there are some I would recommend particularly those with automatic shutoff and alarms if one of the towers has gear box problems or gets mired in the mud. For a 300 ha farm it may require some 4 – 50 ha pivots to cover the entire farm. They should last for at least 10 years with good maintenance and spare parts reasonably available. The land requirements for center pivot are being able to operate in 72 ha square, (848 x 848 m) which seem possible on most farms visited. They are not as sensitive to precision land grading as surface systems.

Multiple Crops

Center pivots can be used for multiple crops such as both tomatoes and cotton under one pivot. However, normally the different crops are in pie shaped field radiating from the pivot instead of normal square fields. Modern system can have sufficient computer controls to make adjustments for the two crops when necessary. They will require a continuous 7 day 24 hour water supply of some 70 l/sec. This represents considerable consolidation of the current water delivery and may require some tough negotiations to obtain, but should be doable.

Organization

Organizationally from an agriculture support services perspective this would be more difficult to organize as center pivots are permanent installations that can only benefit the land on which they are installed and not be shared between farms as the laser leveling equipment can. It thus represents a major capital investment in one farm that needs a secure mechanism for recovery. They certainly should not be provided free.

Managerial Flexibility

Center pivots do not provide a lot of flexibility in water management. You normally get a fixed irrigation application which each circle. Pivots can be speeded up to apply less water and slowed down for more water but within limits of the 24 hour rotation. Also, pressure can be adjusted to increase or decrease the water, if the water source will allow it. However, frequently they simply move continuously around the circle, 24 hours a day 7 days a week. Often when the water supply is limited, such as from a well with declining water yield they have difficulty keeping up with the ET demand, and actually need some supplemental rainfall to catch up with the demand or the crop will slowly become progressively more stressed. For this reason they tend to operate through any showers or thunderstorms, etc. They are mechanical devises and subject to normal mechanical maintenance particularly with the gearboxes for each tower and occasionally getting stuck in the mud. They can be advanced to line up with the fields and allow easy access to the crop for mechanical operations. However, they still are the most cost effective and reliable irrigation system, at least in the USA.

Following up on this possibility would best be done by contacting a company representative for more formal discussion with careful concern for disease control and what can be done to minimize it.

Drip Irrigation for Tomatoes

Overview

Drip is perhaps the most heavily promoted form of irrigation, particularly by those who do not have to pay for it, operate it or maintain it, such as our SIDA friends who insisted on it but did not know what an emitter was, and how easily they can become plugged. It is also the most expensive, sensitive, and complex to manage, with high reoccurring and replacement costs as well as the specific mandate of this consultancy. The heavy promotion of drip irrigation is mostly due to its potential to reduce water use. However, ***its effectiveness in saving water can only be done, if and only if, the minimum application by alternative means, such as sprinkler and surface, is greater that the crop water needs***. Thus it can become important in incomplete canopy crops such as vegetables, but not necessarily process tomatoes for which the vines tend to fill the canopy. The effectiveness of drip is based on reducing the soil evaporation component of the evapotranspiration water loss, while not reducing the plant transpiration. With a full canopy crop that already greatly reduces the evaporation losses and the vast majority of water loss is by transpiration, sprinkler systems can be nearly as efficient as drip systems in meeting the crop water requirements. It must also be recognized that evaporation losses from water on the leaves either from rainfall or sprinkler irrigations are a one-for-one substitute for transpiration losses as the latent heat of evaporation energy is the same.

Primary Use

Thus the main use of drip irrigation for reducing water use comes when water is either very expensive or very scarce. Drip irrigation was first developed in Israel where water was scarce and used mostly for vegetable and fruit crops, and not wheat, maize or other full canopy crops. In the USA some of the initial use of drip irrigation was outside San Diego where the irrigation water supply was treated municipal water which some 15 years ago was valued at $700 /ac.ft. ($0.57/m^3). It was again used for vegetables such as pickling cucumbers. Currently, an extensive amount of buried drip is being installed in Eastern Colorado in response to declining well yields of the Ogallala aquifer falling below the critical ET level for a full circle. Thus the center pivots are not able to keep up with ET rates, and the choice is either wind-shield wipe the Center Pivot, forfeiting half the land, or use drip and irrigate more area. This time the crop is maize but the actual water saving needs some careful evaluations, as considerable amounts could be leaching down from the buried drip line particularly early in the season when roots have not fully developed and reached the tape. The availability and costs for irrigation water in Tajikistan does not appear sufficient to justify the use of drip based on water saving needs.

Secondary Uses

Other uses of drip are for irrigating tree crops in terrain too rugged for sprinkler or surface system. The example is avocado in California being irrigated with micro-sprinklers in the hilly terrain between San Diego and Los Angeles. Drip can also be used to reduce humidity sensitive diseases such as mildew in grapes. In this case the drip lines and emitters are usually suspended on the wires supporting the vines and dripping between individual plants. This would to a lesser degree apply to late blight control of tomatoes, a very legitimate concern with this project, and perhaps the main reason to consider drip systems.

Drip does offer some fringe benefits such as increased field access for multiple frequent picks of vegetable such as pickling cucumbers that have to be picked every 2 or 3 days. Once they shifted to drip irrigation because of water costs they were not forced to wait several days for the surface to dry after typical furrow irrigations. The increased access effectively off-set the extra cost of the drip system.

What is drip Irrigation?

Emitters: Drip irrigation is any of several forms of micro irrigation applicators that place water as close as possible to the plant root, and avoid applying water to areas were plants are not growing. This is done by using small plastic tubing with individual emitters embedded in the tube at approximately the plant spacing or the perhaps connected by capillary tubing to reach individual emitters as in a flower garden. It also includes micro-sprinklers which discharge a small amount of water up to 10 feet from the source. The key to drip systems is the emitters. They are considerably more complex than a simple hole in the tubing, that would result in water spouting out like a leaky hose with different rates depending on how the pressure changes down the line, either decreasing with increased height or loss of water, or possible increasing if going downhill (Fig. 20). Therefore, emitters are fundamentally pressure compensators designed to assure uniform distribution of water along the entire drip line. This is normally done with what is referred to as a torturous track in which the water enters the emitter via a small hole or screen from the main tape and then works its way through many snake like turns while friction loss continuously reduces the pressure until the water emerges as steady drips instead of spouts (Fig. 21). Even the flat tape installed as a demonstration in Geha's garden actually has a second small capillary channel along the seam. Water enters this capillary channel about 20 cm prior to the slit through which the water eventually exits. These emitters typically operate at 2 l/hr. They can also be as simple as a piece of capillary tube with a twist for pressure control as the sample from Zambia (Fig. 22).

Fig. 20. Water spouting from a simple hole in a hose with no means for pressure compensation.

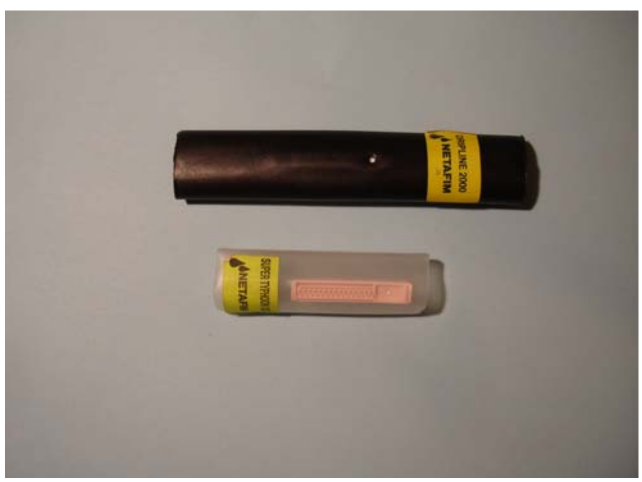

Fig. 21. Behind the clearly visible hole is a torturous track pressure compensator in a typical drip emitter.

Fig. 22. Alternative emitter manufactured in Zambia with the pressure controlled by simply tightening the loop.

Since the water has to pass through these small holes and twists and turns drip emitters are susceptible to plugging by particulate matter in the water, algae and fungi in the water or soil were the water exits the emitter, and mineral crusts formed by dissolved Ca or Mg in the water converting to insoluble Ca and Mg oxides upon exposure to the air as it emerges from the emitter. This all requires an extensive sand filtering system to remove all particulate matter, which is definitely a problem with the turbid surface irrigation water in Tajikistan (Fig. 23). It also requires occasional preemptive flushing of the system with Clorox to kill the algae and fungus before the build up is enough to plug the emitters and also with sulfuric acid to dissolve and move Ca and Mg crust away from the emitters before they plug. This is usually done every couple months during the season.

Fig. 23. Bank of sand filters for filtering water for commercial large scale drip system, even when using well water with limited suspended particulate material.

Management concerns: Other areas where drip irrigation can have problems that require some continuous monitoring is rodents chewing the lines to get to the water, particularly buried drip which is hard to see. While surface systems may increase field access, cultivation around the plant is hindered by the extra time and effort it takes to maneuver around the drip tape with reasonable opportunity for cutting the tape with a hoe or other cultivation implement (Fig. 24). Just ask the factory laborers working the garden around the demonstration how much extra time it takes (Fig. 25). This is a kind of indirect but very real extra cost for drip systems. Finally, a very personal incident from my back yard drip system is my neighbor's roommate discarded a cigarette butt by flicking it at my fence. It actually went through a crack between pickets, landed on the drip line, and melted a hole in it (Fig. 26). This happened while I was on vacation so for up to 6 one hour drip cycles water flowed freely through a 6 mm hole in the drip line. Observing the number of people smoking in Tajikistan and working in the fields this could be a real problem. As a cost saving drip tape is fairly thin and thus easy to cut, burn or melt through.

Fig. 24. Drip demonstration in Zambia showing the complexity of drip lines that need to be weeded around.

Fig. 25. Drip demonstration at Geha Factory that also will require extra time and effort to work around, adding an indirect cost to drip irrigation.

Fig. 26. Cigarette accidentally discarded against my home drip line melted a 6 mm hole in the line.

Chemigation: Drip systems can easily be used for chemigation including N fertilizers and systemic plant protection chemicals, both insecticide and fungicides. Subsurface drip systems can also be used to inject Phosphoric acid for fertilizer.

Service Life: Drip system do have more limited life expectancy and need replacement more frequently then other systems particularly for surface drip systems subjected to the sun's ultra-violet light. In Iraq the locally manufactured material only lasted one season, while imported drip material lasted 2 year or more. Thus the $1000 /ha Netafilm estimated cost of a system has to depreciate in 2 years instead of the same $1000 depreciating over 10 years with center pivot.

Buried Drip: Buried drip systems can last up to 10 years, if they are well maintained. However, buried drip has to be buried deep enough to avoid any tillage implements that may be used to work the soil. That normally means approximately 50 cm below the surface. At this depth it might be difficult for the capillary front to reach the surface except for fairly heavy clay loam soils. If it can not, then the first couple of irrigations have to be surface irrigations until the root are estimated to be within sufficient proximity of the drip tape to obtain the necessary water. Also, buried drip may not be as water use efficient as expected because despite the tutorial video on water movement showing a uniform movement up, down, and horizontally for easy visibility in the video the water was injected into a dry soil. Under more typical field conditions the soil would start considerably moister and thus the influence of gravity would be more apparent and the circle of water movement would sag substantially (Fig. 27). However, this is a difficult type of soil water movement to quantitatively measure. Also, once installed, the field layout is precisely fixed and can not be changed for the life of the drip system. Each tillage operation has to be done precisely beside the drip tape so as not to become entangled with the drip tape. No operating a tractor in the field with a vodka hangover, it just won't work.

Drip Layouts: Because of the limited amount of water individual drip tapes can convey, drip systems tend to be in smaller blocks and sets then surface or other types of irrigation. Typically sets would be no more than 3 ha and 6 sets consolidated into 1 block. The irrigation schedule would then be fixed at 4 hours on and rotated among the 6 sets in a block to allow 20 hours off. With the temperature and humidity in Dushanbe it might be difficult for this watering rate to keep up with the 11 mm daily ET and the system adjusted to 4 sets per block and irrigation 6 hour on and 18 hours off.

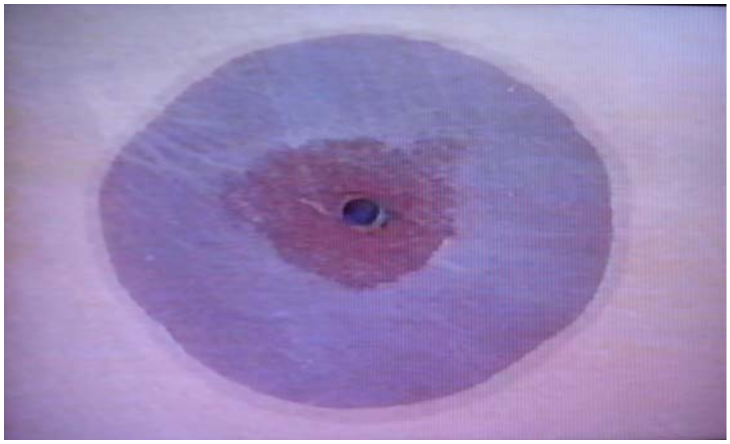

Fig. 27. Picture taken for video of capillary water movement from a simulated buried drip emitter. Video was made with dry soil, and thus most likely under field conditions the circle would sag downward under additional gravity force.

Recommendation: With all these problems I am hesitant to seriously recommend drip irrigation for processed tomatoes at this time. Once the agriculture community has finished shaking down to more economically viable units and farm managers have become more cogent of labor quality, than maybe take a closer look. To follow-up on the prospects you should contact Netaflim in Israel. They are the world leading supplier of drip irrigation equipment and enjoy a solid reputation for the work they do.

Agriculture Support Services

As explained to the consultant and alluded to throughout this report one of the components of the total Geha Foods project was to assist the contract farms with some support services focused on tomato production to assure a flow of tomatoes for processing. This is probably needed and could provide some valuable assistance to the contact farms, extending beyond tomato production. The support services envisioned would include hybrid tomato seeds of an acceptable variety as demonstrated by the current variety evaluation, specialized equipment for transplanting tomato seedlings, and land grading, etc. This should be considered a preliminary list of services, subject to expansion as needs are identified such as prefabricating irrigation control structures. The consultant was asked to comment on at least the mechanization aspects. While not an expert in mechanization and having not heard from a colleague queried for information I will make few only a few comments based on my observations of mechanization in developing areas.

Basic Tractor

If I were to put together a support services unit based on assisting farm with transplanting and land grading, I would base it on either the Massy Ferguson 65 hp or 85 hp tractors. I chose these because they are what I see almost universally around the developing world. Also, as I understand it the spare parts are interchangeable with Russian Universal tractors, but the Massy is of higher quality. The reason for the 65 hp is that it appears the most widely used general purpose tractor that can pull a 3-disk plow and would have no problem with a transplanter. However, if laser leveling is going to be a major component then you might want to go for the bigger units. Please note I am recommending the Massy while being minor a stockholder in John Deere. However, if John Deere has developed a joint venture in the CIS as mentioned if Musk, Belarus, and its machinery become widely available in Tajikistan, then it should be considered.

I would then opt for either 4 or 5 units based on what can be targeted with a laser source. That would provide 4 units with a targeted scraper and one unit for loosening the soil with either a disk plow to chisel plow. I would then get 4 scrapers equipped with laser targets, and I would have them mounted on the 3-point hydraulic rather than towed as this will allow easier turning and working closer to the canal system. With the smaller tractor the scraper on the 3-point hitch should not be too top heavy and can always be counter weighted.

Transplanters

I would also buy 4 or 5 transplanters consistent with the number of tractors obtained, but be careful to make certain they are mechanically the simplest. Again I would have them mounted on 3-point hitch rather than towed to more readily get around the field and into the corners. If you do get into the transplanting assistance, I would insist on producing your own seedlings. That not only gives you control of the variety, but also the flow of seedlings into the machines making certain they are the same age. To have farmers produce the seedling for you to transplant could result in a real mess as instead of having seedlings sown on consecutive days and of uniform age transplanted, they will be of varying age according to the farm with many too old to be conveniently transplanted without some severe damage, etc. as noted in Darrel's report. It should also assist with the overall logistic flow into the processing plant, by staggering the maturing of the tomatoes.

Organizationally

Organizationally, I would have the support services as a totally independent subsidiary and absolutely financially independent of the processing facility. My reason for this is that any repayments for agriculture services provided to the farms should not come from deduction for tomato deliveries to the factory. If this is attempted there is a high likelihood the tomatoes will be side sold instead of delivered. This is based on the use of micro credit programs in smallholder communities throughout the developing world that were linked to farmer cooperatives and repayment leveraged through produce delivered to the cooperative. Virtually universally this has resulted most of the produce being side sold and the micro-credit programs collapse as soon as external facilitation ended. I don't think Geha Foods can afford this. Being an independent subsidiary would allow the support services to expand as opportunities develop independent of tomato production. An example might be completely overhauling all the old tractors, perhaps under contract to some development project as Lyland motors did in Malawi with their old land rovers.

Production Practices

Local Crop Husbandry

One concern I had in listening to some of the discussion around the office is the possible desire to make the tomato production process too complex. It has to be noted that crop husbandry tends to be very provincial so that what is best management in one area may not be suitable for other areas. The differences could be substantial, possibly in the range of 30% and not be easily explained, if at all. Also, most “best management practices” are based on the potential of the physical environment. It is then left to the user to sort this down to the economic optimal based on cost benefits estimates, and then the operational optimum based on the availability of labor, etc. This latter restriction is often overlooked but the best example might be the comparison between the Geha garden and the tomato plots on the various contract farms. The Geha garden definitely looks much better than the farms, but if you look at the ratio of area to labor I think you will see the Geha garden has a much higher labor input to keep it well manicured. It is questionable if the extra labor Geha is using is really economic for the contract farmers to commit, relative to their other commitments.

Thus while it is good to evaluate how tomatoes are produced in other areas, the starting point is what is being done in Tajikistan and congenially negotiate how to modify the management, and not just attempt to impose it. Again, the example might come from the Geha Garden where the workers planted maize in the tomato rows, presumably to provide shade (shadow) for the tomatoes and reduce sun burn (Fig. 28). Similarly, they took the weeds and covered the tomatoes with them, again presumably to provide shade and reduce sunburn (Fig. 29). Both practices are unknown to me from other locations, kind of cute, and were not used on the various contract farms. However, they should not be summarily discarded, but casually evaluated and at least partly kept to make certain the local knowledge and experience of workers did not have some merit, as often is the case.

Fig. 28. Maize Plants Intercropped into tomato thought to provide shade and reduce sunburn on the tomatoes.

Fig. 29. Weeds laid on top of tomatoes possibly for reducing risk of sunburn.

Some of the other things to consider are:

Nutrient soup

I noticed you were applying some kind of liquid to the tomatoes. I looked at the label and frankly could not see any real benefit to it. It proclaims to have some enzymatic effect but that does not make a lot of common plant sense. Plants only take up nutrients as non-organic ions, and I am not certain how enzymes, particularly when applied to the leaves will render ions in the soil more available. There are always on the market some of these promotional solutions that proclaim far more benefits then the produce. Usually, such miracle growth stimulators contain some micro-nutrients that under the right circumstances will show some dramatic effects and give them some promotional material, but most of the time there is no measurable impact. I doubt if the solution is doing any harm, but I seriously doubt if you are getting any benefits from it.

Soil Test:

Soil tests can be a valuable management guidance tool, but do not require extensive use. They are not really sensitive to details regarding past crop history, etc. as mentioned in some discussions. In the USA most farmers obtain soil test information each year through their fertilizer dealers, who provide the service free to their customers. The actual cost is around $18 per sample. However, if you really ask carefully the main benefit is to provide the dealer an opportunity to visit the farmers once a year to plan their fertility program. In Maryland the head of the University's lab acknowledged that the biggest contribution of the state soil testing program was to gradually increase the Mg in the soils as a result of recommendations for dolomite limestone on acid soils in place of regular limestone. Also, analysis is very specific to the lab that does the analysis. Different labs use different extraction procedures and come up with different results that could vary as much as 20%. Usually, this is again very effective for the location or region where it was done as the analytical procedures are adjusted to the dominate soils in that region. Extracting the results from outside that region can be difficult. Thus, if you do soil testing, it should be done locally, and interpreted locally, even if it takes six weeks to get the results. Just allow that much time between collecting the soil samples and when you need to start using the information for fertilizer applications. The soil conditions won't change any measurable amount during that period. It would not be good to send samples back to the USA or Europe for analysis even if you could get the phytosanitary import permits and sterilize the soils for shipping. The shipping costs would not justify it as well as the relevance of the results.

If you are going to take soil samples you really only need one composite sample from each field. Take a hand trowel full of soil from the surface of 10 to 12 locations throughout each field, mix them together into a composite and submit about a kilo of soil. Do not try and get a sample from each ha, the data will simply overwhelm you and the analysis confuse you.

Most soil tests provide information on soil texture by feel like I was doing (Fig. 30). The Geha Garden is sandy loam while most of contract farms were silt or clay loams. Soil test then provide pH, organic matter, salinity if regionally important, and most of the major nutrients, such as N, P, K, S, Mg, and Ca, plus some to the micro nutrients again depending on what may be regionally important. Of these, you can discount the organic matter and N. The organic matter because there is really very little you can do about it. Most of what can be added with green manure crops, compost, manure etc. is easily decomposable material that will disappear in a couple weeks after being incorporated. The N because it is very unstable and you are usually better off figuring on zero carry over, and adding the full amount needed. It will be the largest component of any fertilizer you apply. The pH is important as it determines the availability of other nutrients. However, adjusting it can be a big task. If it is too acid it will require several tons of limestone per hectare to correct or if too basic an equal amount of gypsum. My guess it will not be a major problem as I expect your soils to be neutral or slightly basic. The rest of the nutrient elements will provide a good estimated of some long term fertilizer nutrients. All of them are stable in the soil, so if you apply too much is will go into the soil nutrient bank. This then becomes a mechanism for long term fertility evaluation to bring the deficient nutrients in balance. Generally, you really only need take soil samples once in every 4 or 5 years, or whenever a field is rotated into tomatoes. At this time the analysis would be a nice much appreciated service to the farm chairmen.

Fertilizer Sources

Some mention was made of importing fertilizer. I would be very careful about this. Somewhere in Tajikistan there must be a natural gas supply as they do manufacture Urea nitrogen as I was using that last fall in Afghanistan on the seed and fertilizer voucher program. I also assume they have dealers dealing with DAP (Diammonium Phosphate) and other fertilizer mixtures. I would expect the quality is good. However, the soil testing labs should be able to verify the nutrient concentration of any fertilizer. The only exception to local purchase would be some specialty fertilizers involving micronutrients, and then only in response to clearly visible nutrient deficiency symptoms. These may have to be imported but better to work with the established fertilizer dealers. Most likely they are in a better position to deal with all the informal needs of getting import approvals.

COOPERATIVE EXTENSION SERVICE
AND EXPERIMENT STATION

GEHA Foods

SOIL, WATER & PLANT TESTING LABORATORY
COLORADO STATE UNIVERSITY
FORT COLLINS, COLORADO 80523-1120

NUMBER OF SAMPLES 1
DATE RECEIVED 7/6/2006
DATE REPORTED 7/12/2006
COUNTY

SOIL TEST REPORT

IDENTIFICATION		ROUTINE SOIL TEST RESULTS													
Lab No.	Field Number	pH	Salts mmhos/cm	Lime %	Texture Estimate	SAR	Gypsum meq/100g	Organic Matter %	Nitrate N ppm	Phosphorus P ppm	Potassium K ppm	Zinc Zn ppm	Iron Fe ppm	Manganese Mn ppm	Copper Cu ppm
H	planter mix	7.6	3.4	Low	Loam	3.5		6.5	11	42.4	902	12.6	44.4	18.2	4.9

I. D.	FIELD INFORMATION					RECOMMENDED FERTILIZER (LBS/A)							OTHER		
Lab No.	Acres	Irrigation	Last Crop	Yield Last Crop	Manure T/A	Proposed Crop	Yield Goal	N	P_2O_5	K_2O	Zn	Fe (Iron)	Mn lbs/A	Cu lbs/A	Gypsum T/A
H						planter mix									

IMPORTANT INFORMATION ATTACHED
Visit our web site at: http://www.colostate.edu/Depts/SoilCrop/soillab.html

APPROVED ______________________ Ph.D.
TITLE Extension Soil Testing Specialist

Fig. 30. Sample of soil test results

Collaboration & Facilitation

In observing the interaction between Geha Foods and the various Farm Chairmen of the contract farms, I became concerned if the necessary collaborative and facilitative relationship, essential for assuring the necessary flow of produce to the processing facility, could be established and maintained, and with that the overall success of the plant. While in the construction and operation of the processing plant a strict supervisory relationship is possible with employees and quality control essential for obtaining building materials, I don't think this can be extended to working with the farm chairmen in the production and procurement of the tomatoes for processing. Instead the relation with the different contract farm chairmen has to be very much a collaborative and facilitative working relationship given due respect for the knowledge and experience of the chairmen in local tomato production as the starting point for evolving the tomato management and irrigation water management toward what was highlighted by Darrell and myself in our respective reports. It also has to be done with full recognition that the farm chairmen are not solely in the tomato production business, but have to integrate the tomato production with other farm enterprises particularly the possible highly leveraged cotton production. The relationship with the farm chairmen can not be one of dismissive of their knowledge or skills in managing a complex multi-enterprise farm.

Recruiting Staff

A final interest was expressed in internationally recruiting a plant manager and a production coordinator to oversee the processing facility and working with the farm chairmen to assure the best possible flow of produce to the processing facility. The idea is to find people who have been educated and have worked in the USA or Europe, but with a cultural heritage in former Soviet Union particularly the Central Asian Republics. One way to identify potential individuals would be to work through the USA Agriculture Universities. They form a collective entity known as the Land Grant University System. This is based on a law passed in 1862 called the Morrill Act. It provided one university in each state a grant of land in what at that time was the undeveloped western part of the country with the obligation to use the land or funds derived from the sale of the land to develop and support an Agriculture College. An internet search for "Land Grant Universities" identified this website www.csrees.usda.gov/qlinks/partners/state_partners.html. The website contains a map showing the location of the different land grant universities that can then be clicked on to get to their primary website. I would concentrate on the 1862 Land Grant Universities as they are the primary ones (See Appendix). The 1890 universities are the historic black universities and the 1994 universities are historic native american universities. Both tend to be much smaller with very limited international students. On on the website of the respective universities I would look for the offices of international programs. That office should be keeping track of all international alumnae, both graduate and undergraduate. They should have a means of contacting them and you can send a message to there asking them to provide you a list of potential graduates along with the latest contact address they have for the individuals. You can then contact them directly. I would suggest you request graduates in Food Science for a plant manager, and graduates in either Agronomy or Horticulture for the production coordinator. The message to the different universities can be quite simple such as:

Geha Foods is building a tomato processing plant in Dushenbe, Tajikistan. We are seeking to fill the positions of plant manager and tomato production coordinator. We would like to identify graduates from land grant universities in Food Science, Agronomy or Horticulture who are from Tajikistan, other Central Asian Republics of the former Soviet Union, or from the Russian Federation. If you provide us the names and lastest address you have on file for any graduates that meet these qualifications we would greatly appreciate it. We will then proceed to contact them individually. Thank you for your assistance.

An alternative means of identifying potential staff would be to put a notice in one of the international recrutiment email list such as DevelopmentEx. They can be contacted through their website www.developmentex.com.

Summary and Conclusions

Agriculture in Tajikistan may best be described as still in a state of flux resulting from the breakup of the former Soviet Union and need to convert the former State and Cooperative Farms into competitive economically viable enitities. Meanwhile, the are trapped in a highly labor intensive, low labor productivity system that represents some deeply intrenched poverity for most of the farm residents. This also affects the current irrigation management and how it can be improved.

The irrigation system appears to be a surface system that is free flowing all the way to individual fields of 15 to 20 ha. The result is very limited flow to each field and difficulty getting enough flow into individual furrows to quickly push the wetting front through the fields. The result is excessive irrigation applications with substantial over irrigation leaching to the water table and back to the river.

The irrigation also tends to be directly down the slope which could be as steep as 3%. This then allows for substantial furrow erosion. The fields also are not smooth and often contain benches where water will slow and pond before continuing to the end.

Improving the irrigation system for tomato production can be done by:

1. Renovating the existing surface system
2. Shifting to some form of sprinkler system such as center pivot
3. Shifting to some form of drip system.

Of these the most practical that Geha Foods could assist with would be to renovate the existing surface system. This will have to be done slowly over several years and have to be done in close coordination with the various farm chairmen. The process will require improving the water supply to individual fields to assure there is enough water to more rapidly and effective irrigate each furrow. This in turn would imply replacing the present improvised check and control structure to more permanaent structures with control gates that could concentrate more water on individual fields and rotate between fields. The next process would be to shape the land with laser land forming equipment to remove the soil benches in the middle of the fields and grade the furrows to a non erosive 1% or less. The next phase would be to install head ditches that can uniformly apply water to all furrows in the reach and not rely on small cuts in the head ditch that allow for different flow rates and irrigation rates for different furrows. Finally, the need is to develop an irrigation master plan for each farm that will rotate water between the different fields to provide each with an opportunity to irrigate efficiently.

It is possible to shift to sprinkler systems but this needs to be done with care because of increase canopy humidity that could encourage various diseases. Also, drip would be possible but it is most likely too expensive and complex a system for the current conditions in Tajikistan.

The agricultural services for the contract farmers when done in a sensitive collaborative manner could provide some valuable assistance to the farmers and assure the timely delivery of produce for processing. However, it should really be managed as a totally indepenent subsidary with payments for services not linked to the processing facility. This could result in substantial “side-selling” and undermine the processing facility.

Appendix

Annoted Itinerary

Correspondance on Evapotranspiration Computation

Correspondance and Article on Center Pivot Irrigation

Land Grant University System

Tajistan Gaha Foods Field Log

R.L. Tinsley

16 June — Friday, Arrived in Dushanbe at 03:00 am after 30 hour flight. Was given day to sleep and recover with no work assigned. Did meet with director of Winrock Farmer-to-farmer program for quick briefing and orientation to operations of guest house, plus do some minimal grocery shopping.

17 June — Saturday this also a rest day thus continued to recover from jet lag plus taking some time to visit Dushanbe. As Winrock office was closed nothing else was possible.

18 June — Sunday also the weekend but was able to organize day hike with group to the mountains near the new tunnel to be opened shortly.

19 June — Monday, first real day of assignment. After late start visited Geha headquarter, the sight of processing facility under construction, after brief stop at Chamber of Commerce to facilitate shipment clearance, which will require some extra effort. I visited small garden at the headquarters that included some research/demonstration plots. There was also a small demonstration of drip systems. Most was surfaced irrigated but system really too small to fully evaluate. Soil was sandy loam.

20 June — Tuesday, I made first farm visit to the Gissar area with visits to the President's Garden, 50 Years of October, and Latif Murodov. I toured the research/demonstration effort for the 30 varieties of hybrid tomatoes that were being evaluated and had recently been transplanted. The experimental layout was individual plants in a row, spaced on border rows in larger field. All would be classified as border rows with no interior rows. Now valid for research reporting, but ok for company demonstration seeking some varieties they could promote for processing. I am somewhat concerned with heat stress as summer temperatures in exceed 45◦C. This also means the ET rates could exceed 7 or 8 mm/day, and be difficult to keep up with except for surface irrigation. Ask Troy if he could run a max ET rate.

Also took note of the irrigation system, it was all surface irrigation that required individual management for each furrow. Very time consuming by Colorado standards. The rows actually ran direction down hill, with about 3% slope which is sufficient for some erosion to occur. There did not appear any serious land grading effort. Soils were clay loam with sufficient cracking so that crust forming by irrigation would be partly broken and allow considerable infiltration of water before sealing and reducing infiltration to unacceptable levels. If remaining in surface irrigation, need to consider gated pipe and possible surge systems. The gated pipe might be good with the overall field slopes and allow more furrows to be irrigated at one time as well as cutting down on labor needs. Freed labor should have plenty to do in improving the quality and returns to the crop.

Field size was substantial with a total farm size of 300 ha, roughly one section of land USA standard. This should be suitable for center pivot irrigation. See know major problem except initial dry field infiltration would handle 5 minute opportunity time on the end tower. The infiltration rate most likely would exceed some 12 inches per hour. Center pivot is certainly worth considering given the land size and normal overall cost effectiveness of the CP system as noticed of Colorado farmers shifting to it in response to reduced labor problems and low pressure system now widely used. Need to contact the manufactures.

Visited second farm. It was similar in field size and soil type with most of the land in cotton. However, they did have some water running so I could get some photograph as to how the water flowed down the head ditch and into the furrow. Did note the wetted parameter extend only 15 to 20 cm above the water surface, not really sufficient for buried drip at the 45 cm needed to get below the tillage implements. Also, looked and photographed the drop structures in the canal. They looked in basically poor condition with debris jammed on the weir and no one really concerned with its presence. I don't think you could get an accurate measurement, and not certain it is important. I would have to get some idea of water rights and water management within the canal system to determine this.

21 June Busted field day. I started with discussion with Helmut concerning transplanting equipment. I will have to follow up on Massy Ferguson and John Deere websites. Tried field visit to Vamdat area but could not locate the farm chairman. After waiting until noon, returned to headquarters to try again tomorrow.

22 June Made field visit to Rudaki area and Ulchaboi farm spent 45 min visiting with chairman of the farm at his home before visiting the field. Then we visited two variety production demonstrations. Looked ok but remained concern with the heat and need for varieties with good heat tolerance. Irrigation was similar but the runs were longer, perhaps 200 m. Still think only few furrows irrigated at a time, perhaps only one. Control structures were in need of extensive renovation to become more effective.

I remain interested and concern with privatization of the former state farms. It looks like the farmers were originally subdivided into individual plots, with each member given at least one plot and perhaps 3 as reported from other areas. With the irrigation set for large fields this would be virtually impossible to manage in areas were irrigation was absolutely the only means for growing a crop. Thus it was logical to reconsolidate the management. However, the prorated land holding per family is probably too small to be economically viable in the long run. My recollection from Uzbekistan is that dividing the number of families on a state farm by the acreage yield the typical subsistence smallholder farm, and a farm of similar size and crop in the USA was father, son and hired mechanic operation only. Thus, there is a need to expect some migrating out looking for better jobs. This should be at least tolerated, if not slightly encouraged. It is also need to learn the lessons of Gizeria Scheme the

British built in Sudan just outside of Khartoum between the two Nile Rivers. Here they consolidated smallholder into unified management and created the biggest irrigation disaster in history. The out migration, if and when it occurs, needs to be orderly and not leveraged. The idea that laborers will work for the right to cotton sticks for fuel after harvest, and allow the farmers to accumulate debts against their shares in the farm could result in people being leveraged off the land with the chairman quietly becoming the sole owner. This might make for better farm management on the scale of irrigated farming in the US, but a social disaster.

Given the reconsolidated management, improving the on-farm water distribution system and irrigation management to come closer to that of the Western USA still using surface irrigation, should be a fairly simple and straight forward. It would mostly entail braking the fields into 20 ha units, doing some laser land shaping, consolidating the flow, renovating the on farm control structures including the intake from the main canal, and putting in suitable head ditches or gated pipe locations, etc. It should than be possible to irrigate 20 ha blocks with little labor inputs and rotate through the farm on a weekly basis.

23 June Remained at headquarters all day, did some computations on ET based on message from Troy indicating at 45°C and 25% relative humidity the ET would be 11 mm or more. This translated to 1.3 l/sec/ha or 390 l/sec for 300 ha farm. Also, discussed agriculture equipment needs with Helmut, resulting in the need to contact Norman.

24 June Continued field visits, this time returning to area where we failed to contact the farm chairman. Observed several active irrigation programs of tomatoes. Outlook similar, with some more furrows being irrigated simultaneously, but with insufficient flows and a lot of water loss from different diversion both control structures and informal cuts. Some furrows were actually stalled.

After noon was lunch party for expatriate staff and others. Very nice.

25 June Sunday, and day off. Spent the day loafing around the guesthouse and catching up on personal communications, etc. Did meet with Bill Bell for dinner and he provide reasonable briefing on the irrigation system. Basically, there is plenty of water from snow melt that last throughout the irrigation season, particularly in the areas commanded by the hydroelectric dams. Some scarcity problems, but could be more managerially induced than shortage. It looks like some of the irrigation operations are based more on informal income opportunities than overall master plan. This quickly leads to uncertainty at the farm level and forces farmers to concentrate on irrigation according to opportunity rather then organized schedule. The only real logical choice available to them, even if it means over irrigation and more overall water management, including considerable return flows.

Discussions with Bill continued on some overall aspects of the agriculture program. It seems based solely on cotton quotas, with regional agriculture managers' jobs at stake for not meeting quotas, even with highly depressed farm gate price. This can then translate into certificate lease authorization and clause saying lease good only for beneficial use of land defined as cotton production. Reason being government generates considerable income from cotton sales based on depressed farm price. Appreciate that farmers or farm laborers are getting the worst of the deal. I get the feeling of Frank Norris's "The Octopus" is coming into play with big business or big government pushing farmers out of business i.e. USA California at turn of last century. Not good!!

26 June	Monday, remained at factory headquarters drafting report. Delegation from European Bank for Reconstruction and Development visit and joined them from lunch including essential toasting.
27 June	Tuesday and official holiday. Again remained at the factory headquarters and worked on report draft.
28 June	Wednesday. Visited fields with Agronomy farm advisor, including collecting field layout and ledger for farm designated for tomato production and proceeded to farthest area, which was more hilly.
29 June	Thursday, Reviewed the ledger and photo graphed the field layout map in high resolution for making detailed printouts of each field.
30 June	Friday, remain most of the time at factory working on report, but did make an effort to visit field, but too late to meet chairman.
1 July	Saturday, final field visit to look at individual fields to be involved in tomato production, developed understanding of extent of knowledge of irrigation principles by farm chairman and realization he understood but did not have the financial resources to implement. Forced major revision on draft report.
2 July	Sunday, rest day
3 July	Monday, Remained at Factory working on draft report, gave quick briefing to Helmut as he was departing Tuesday for Europe and daughter's wedding.
4 July	Tuesday, Worked on Draft Report at Winrock Office, with Helmut off to Europe no real need to visit factory.
5 July	Wednesday, Continued drafting report.
6 July	Finished drafting report and provide debriefing to Winrock Staff.
7 July	Departed for the USA

Correspondance on ET computation

From: "T. Bauder" <troy.bauder@colostate.edu>
To: "Dick Tinsley" <r.tinsley@cgnet.com>
Subject: Re: Quick ET computation
Date: Thursday, June 22, 2006 5:47 PM

Dick,

probably around 11 mm/day or greater. What is the elevation?

Troy

At 05:24 PM 6/21/2006 -0600, you wrote:
>Troy,
>
>go ahead and assume clear skys. I have not seen a cloud all week. I am
>really looking for a realistic maximum ET for discussion purposes.
>
>Dick
>______________________________
>Developing Smallholder Agriculture: A Global Perspective - R.L. Tinsley
>AgBe Publishing, AgBe@Skynet.be; US$49 +S&H, Website:
>www.smallholderagriculture.com
>
>----- Original Message ----- From: "T. Bauder" <troy.bauder@colostate.edu>
>To: "Dick Tinsley" <r.tinsley@cgnet.com>
>Sent: Wednesday, June 21, 2006 4:40 PM
>Subject: Re: Quick ET computation
>
>
>>Dick,
>>
>>Should I assume clear sky radiation and estimate from your latitude or
>>are you getting any cloud cover?
>>
>>Troy
>>
>>At 08:03 AM 6/21/2006 -0600, you wrote:
>>>Troy
>>>
>>>PM today is great. I am operating 11 hours ahead of you.
>>>
>>>Dick
>>>______________________________
>>>Developing Smallholder Agriculture: A Global Perspective - R.L. Tinsley
>>>AgBe Publishing, AgBe@Skynet.be; US$49 +S&H, Website:
>>>www.smallholderagriculture.com
>>>

>>>----- Original Message ----- From: "T. Bauder" <troy.bauder@colostate.edu>
>>>To: "Dick Tinsley" <r.tinsley@cgnet.com>
>>>Sent: Tuesday, June 20, 2006 4:30 PM
>>>Subject: Re: Quick ET computation
>>>
>>>
>>>>Dick,
>>>>
>>>>Tomorrow pm too late?
>>>>
>>>>Troy
>>>>
>>>>At 08:03 AM 6/20/2006 -0600, you wrote:
>>>>>Troy,
>>>>>
>>>>>If you have a couple minutes could you do a quick ET computation for
>>>>>me for Dushanbe. I am concerned as the temperature appears to exceed
>>>>>45 degree C for a large portion of the summer.
>>>>>
>>>>>Thus could you input the data with:
>>>>>
>>>>>Max temp 45 degree C
>>>>>Min Temp 25 degree C
>>>>>Relative Humidity 25%
>>>>>Latitude 38 degrees 35 minutes N
>>>>>Wind minimal
>>>>>
>>>>>Is this enough? If not plug in any additional at 1 or other neutral value.
>>>>>
>>>>>Thank you,
>>>>>
>>>>>Dick
>>>>>
>>>>>_______________________________
>>>>>Developing Smallholder Agriculture: A Global Perspective - R.L.
>>>>>Tinsley AgBe Publishing, <mailto:AgBe@Skynet.be>AgBe@Skynet.be; US$49
>>>>>+S&H, Website:
>>>>><http://www.smallholderagriculture.com>www.smallholderagriculture.com
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Correspondance on Use of Center Pivots for Tomatoes

My Inquiry

From: Dick Tinsley [mailto:r.tinsley@cgnet.com]
Sent: Tue 6/20/2006 8:26 AM
To: Primm, Pamela R.
Subject: Center Pivot use on Processed Tomato in Tajikistan

Greeting,

I am a Colorado State University water management faculty member on a short term consultancy with an organization establishing a tomato processing business in Dushanbe, Tajikistan. Looking at the fields they look well suited for center pivots. Could you therefore answer a few questions for me?

1. How extensive is center pivots used for processed tomatoes?

2. Is there any problems with tomato blight when use for tomatoes?

3. When you get away from the US quarter section center pivot into less confined areas what is your typical size of your systems and how many Ha will they cover?

4. If the temperatures get up over 45 degrees centigrade will a center pivot be able to keep up with ET, or with the plant under go some level of stress?

5. Do you have an representatives in Tajikistan or elsewhere in Central Asian portion of the former Soviet Union?

6. What would be the rough estimated cost for a complete center pivot system installed here? This is just ball park value I can review with my client.

If you can provide answers to these questions it would be greatly appreciated.

Thank you for your consideration and assistance.

Sincerely yours,

Dick Tinsley
Prof. Emeritus
Soil and Crop Science Department
Colorado State University

____
Developing Smallholder Agriculture: A Global Perspective - R.L. Tinsley
AgBe Publishing, AgBe@Skynet.be; US$49 +S&H, Website:
www.smallholderagriculture.com

Response from Heinz

From: "King, Gary" <Gary.King@us.hjheinz.com>
To: "Dick Tinsley" <r.tinsley@cgnet.com>
Subject: RE: Irrigation of processed tomatoes
Date: Tuesday, June 27, 2006 12:04 PM

Hi Dick,

Sorry for my delayed response as I was on vacation.

I will address your questions in CAPS

-----Original Message-----
From: Dick Tinsley [mailto:r.tinsley@cgnet.com]
Sent: Friday, June 23, 2006 8:28 AM
To: King, Gary
Subject: Irrigation of processed tomatoes

Dear Gary,

I am Dushanbe, Tajikistan on a short term consultancy planning irrigation for processing tomatoes. The area looks suitable for center pivot use, but I was wondering if center pivot is suitable for tomatoes or will there be problems with blight. [King, Gary (STO)] CP IS NOT COMMONLY USED IN TOMATOES - IT IS DIFFICULT TO APPLY THE WATER AND NUTRIENTS PROPERLY WITHOUT CREATING MICROCLIMATES WHERE BACTERIAL AND FUNGAL PROBLEMS OCCUR - ARE YOU PLANTED IN A CIRCLE OR IN STRAIGHT ROWS? I think blight has a canopy humidity factor to it. I also noted that most of the processed tomatoes in California are still surfaced irrigated. Is that correct and if so any particular reason why? [King, Gary (STO)] 60% OF CALIFRONIA TOMATOES ARE FURROW IRRIGATED ~ 35% ARE DRIPPED AND DRIP IS GROWING IN POPULARITY - REASOSN- DRIP IS EXPENSIVE AND THE TRANSITION IS SLOW AS A RESULT - WATER IS NOT CHEAP BUT CHEAPER THAN A BIG INVESTMENT IN PUMPS, LINES AND FILTER INJECTORS - TRANSITION IS OCCURING. ANOTHER ISSUE IS WITH BURRIED DRIP THERE IS

A MULTI (4-5) YEAR COMMITMENT REQUIRET TO MAKE IT PAY - THIS SEVERLY LIMITS ROTATION OPTIONS. Or is water still cheap? I recognize I have been in the area for about 15 years but I recently talked about this project with someone from the area and it was his impression that it was still all surfaced irrigated. We are looking at some of your varieties in our small variety evaluation work.[King, Gary (STO)] WE HAVE SOME VARIETIES THAT ARE VERY WELL SUITED TO HIGH HEAT AND OFFER GOOD COVER FROM SUN BURN - WHAT ARE YOUR HIGH TEMPS DURING SET AND WHAT IS YOUR ELEVATION - ALSO WEATHER PATTERNS WOULD BE USEFUL 45(104) SHOULD BE OKAY FOR OUR BETTER HEAT SET TYPES

WHERE ARE YOU SOURCING OUR VARIETIES AND WHICH ONES ARE YOU TESTING?
WHEN IS YOUR PLANTING SEASON - IS IT DIRECT SEEDED OR TRANSPLANTED (PLUGS OR BARE ROOT)
HOW IS THE WATER QUALITY AND WHAT ARE THE SOIL CONDITIONS

WHO WILL BE PROCESSING THE ROMATOES AND INTO WHAT PRODUCTS FOR WHAT MARKETS

GOOD LUCK AND KEEP IN TOUCH!

GK

Also, how tolerant are tomatoes to heat. We are currently experiencing temperature around 45 degrees C or 104 degrees F and expected to get warmer. Will that be a problem? I do know is Basra, Iraq they had to delay planting tomatoes because of heat problem in summer.

Thank you for your information and assistance.

Sincerely yours,

Dick Tinsley
Colorado State University

____
Developing Smallholder Agriculture: A Global Perspective - R.L. Tinsley AgBe Publishing, AgBe@Skynet.be; US$49 +S&H, Website: www.smallholderagriculture.com

<u>Response form Valmont</u>

From: "Ben" <benny_ob@yahoo.com.au>
To: <rberkland@valmont.com>; <r.tinsley@cgnet.com>
Cc: <vladimir.harminc@valmont.com>; <mwest@agfinplus.kg>
Subject: RE: Center Pivot use on Processed Tomato in Tajikistan
Date: Monday, June 26, 2006 1:23 AM

Dear Prof. Tinsley

Last year I grew one whole hectare of processing tomatoes in Tajikistan as a trial rotation/alternative crop for cotton. Like most NGO projects we received funding late and machinery we purchased didn't arrive until season nearly finished. However with the use of some imported varieties, some good fertilizer management and more frequent irrigations the farmer yielded over 40 tonnes, well above the average in the Sugd Oblast. As the crop was late the farmer managed to catch a shortfall in supply and made a killing selling a fair portion into the fresh market.

We imported 2 by 2 row transplanters and seedling trays, cultivators, boom sprayers, bedformers and power harrows, all for vegetable production. I am unsure of what is happening to the equipment however I have copied Martin West on this email who is responsible. I prepared an analytical report that included budgets for the project that, with Martins permission, I could forward to you if you think it useful.

Any further questions please email.

Cheers ben

Ben OBrien
Azerbaijan: +994 050205764
Australia: +61 417634682
benny_ob@yahoo.com.au

Second Response from Valmont

-----Original Message-----
From: "Berkland, Richard "<rberkland@valmont.com>
Sent: 25/06/06 6:02:54 PM
To: "r.tinsley@cgnet.com"<r.tinsley@cgnet.com>
Cc: "Harminc, Vladimir "<vladimir.harminc@valmont.com>, "benny_ob@yahoo.com.au"<benny_ob@yahoo.com.au>
Subject: FW: Center Pivot use on Processed Tomato in Tajikistan

Dear Prof. Tinsley,

I will forward your e-mail to Vladimir Harminc who has extensive experience in Central Asia. He can address several of your questions regarding our representation in this area. I am currently in Azerbaijan where we are currently managing three comprehensive agricultural projects on cotton and sugar beets and will discuss these questions with him.

We also have Ben O'Brien on our staff in Azerbaijan who has experience in Tajikistan and could be helpful as a resource.

We do not currently have representation in Tajikistan but we can service the country from other nearby locations with experienced personnel.

I have visited several large scale process tomato farms in South America which utilize pivots and export Tomato paste to Italy. Irrigating process tomatoes has been practiced very successfully for many years.

Fifty hectare pivots are still the norm in most of the world due to water infiltration and management issues. We were just lucky 150 years ago as we prepared for pivot irrigation west of the Mississippi.

We have extensive populations in much more challenging climates then Tajikistan. 45 degrees is not a problem to keep-up with if the systems are designed correctly from the beginning.

A budget of $1,000 per hectare can be used for basic pivots with a size of 40-80 hectares delivered to Tajikistan. Sophisticated options could increase this cost if required by 20%.

I hope that this answers most of you questions. I will be back in my office after the fourth of July. My phone number is 402 359 6015.

Best Regards,

Rich Berkland
Valmont Irrigation

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Send instant messages to your online friends http://au.messenger.yahoo.com

Third Response from Valmont

From: "Stolte, Michelle E." <mstolte@valmont.com>
To: <r.tinsley@cgnet.com>
Cc: "Berkland, Richard " <rberkland@valmont.com>
Subject: FW: Center Pivot use on Processed Tomato in Tajikistan
Date: Monday, June 26, 2006 8:14 AM

Professor Tinsley,

Attached is a link to a story about pivots on tomatoes that appeared in our Valley Magazine in the Spring of 2005.

http://www.valmont.com/asp/irrigation/valleymagazine_story.asp?id=94&issue=archives

Regards,
Michelle Stolte

-----Original Message-----
From: Berkland, Richard

Sent: Monday, June 26, 2006 12:34 AM
To: Stolte, Michelle E.
Subject: FW: Center Pivot use on Processed Tomato in Tajikistan

Michelle,

Do you have any stories or pictures you can send to Prof. Tinsley?

Thanks,

Rich

-----Original Message-----
From: Berkland, Richard

Sent: Sunday, June 25, 2006 8:03 AM
To: 'r.tinsley@cgnet.com'
Cc: Harminc, Vladimir ; 'benny_ob@yahoo.com.au'

Subject: FW: Center Pivot use on Processed Tomato in Tajikistan

Dear Prof. Tinsley,

I will forward your e-mail to Vladimir Harminc who has extensive experience in Central Asia. He can address several of your questions regarding our representation in this area. I am currently in Azerbaijan where we are currently managing three comprehensive agricultural projects on cotton and sugar beets and will discuss these questions with him.

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Rich Berkland
Valmont Irrigation

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Referenced Article

Tomatoes by the Ton

Valley pivots help ensure a top quality tomato crop able to withstand the rigors of mechanized harvesting and transport.

Quality is always the first criteria. Unless the irrigated tomatoes Abbett Farms LLC, LaCrosse, Indiana, produces under contract for Red Gold are the proper size, shape and color, no one is satisfied. Then and only then are these vine-ripened Roma tomatoes flavorful enough for Red Gold's award-winning canned peeled tomatoes, juices, pastes, ketchups, salsas and soups. A timely harvest and total crop yield are also important, but quality comes first.

Achieving these results year in and year out is a unique challenge. The tomato, you see, is a finicky fruit . . . yes, botanists classify the tomato as a fruit. It takes a lot of water at the right time and in the right amounts to produce an average of 35-40 tons/acre of Roma tomatoes. Yet, the tomato plant abhors "wet feet," according to Louis Abbett--founder of this multi-generation family farming operation--and his son, Glenn. To meet the tomato plant's need for water and to overcome its aversion to soaked soils, Abbett Farms uses raised beds and timely center pivot irrigation.

From Towable to Precision Corner

An early adopter of mechanized irrigation, Abbett Farms purchased its first Valley center pivot, a towable, in 1977. Today, they operate more than two dozen Valley machines, the newest of which feature cams™ Pro2 panels. Their most recent addition was a 155-acre Valley Precision Corner machine which they used to irrigate tomatoes, seed corn and soybeans in 2004. They also raise field corn and some green beans in rotation with contract tomatoes. "Ideally we'd like 7-8 years between tomato crops on a field, but we can go back to tomatoes in as few as 5-6 years depending on the soil condition and other factors," Glenn Abbett
explains.

One of several varieties of Roma tomatoes are planted at regular intervals so that harvesting takes place on a precise schedule. Their contract calls for a target yield of 37 tons/acre. Beginning around August 20th each year, an average of 11 truckloads carrying 22 tons of tomatoes each leaves the farm every 24 hours. "Harvest time is pretty hectic around here even though we're only picking around 7 acres each day," he reports. When the last truck departs the farm in late fall, they will have delivered 550 truckloads and more than 12,000 tons of fruit.

"Roma tomatoes, in addition to being a great tasting tomato, have a skin that can withstand the rigors of mechanized harvesting. In transport they can be stacked 3'-4' high, and they hold up well going through the processing plant," Louis Abbett confirms. "From a grower's perspective, our slightly acidic, silty clay loam soils, some of which are fairly heavy, give these Midwest tomatoes a distinct flavor advantage." Of their nearly 3200 total crop acres, only about 10%--330 pivot-irrigated acres in 2004--produce Roma tomatoes each year. Yet that crop generates about half of the farm's total farm gross income from crop production.

50-Years Serving Midwest Growers

Abbett Farms was one of the first in northern Indiana to recognize the benefits of center pivot irrigation, says Tom Frank, Chester Inc., Valparaiso, Indiana, the Valley dealership that sold Abbett Farms their first as well as their most recent machine. "They first used a Valley towable pivot to raise seed corn on three adjacent fields," Frank explains. "But as they and other growers increased irrigated crop production, they quickly adopted stationary center pivot, corner and linear systems. Growers want irrigation equipment designed for maximum field coverage to reduce labor, conserve water and obtain optimum energy efficiency. Valley systems allow us to accomplish this on various field sizes, using everything from a single span 10-acre pivot to a 640-acre machine."

Chester Inc. has been serving the needs of area growers for more than half a century, now from their new office complex and company headquarters near the airport in Valparaiso. Although officially retired, Charles F. Bowman, one of the company founders, keeps abreast of company progress. It was Bowman and Orville Redenbacher--who's name is still attached to the popular popcorn brand they originated--who were instrumental in the company's diversification into other agricultural areas, including mechanized irrigation. Today, Larry Holt and Deb Mrozinksi operate the Agricultural Systems division of Chester Inc.'s business. In the field, Tom Frank provides direct sales support for Abbett Farms LLC and dozens of other customers. "We benefit from excellent moisture from natural rainfall during the growing season," Frank explains, "but rainfall alone is not enough to support the specialty crops like seed corn, tomatoes, potatoes, green beans and mint that are producing high profits for area growers."

Irrigating Tomatoes Efficiently

Center pivot irrigation plays a role at every stage of the tomato plant's life. At planting, two rows of tomato seedlings are deposited into 5'-wide raised beds. To minimize transplant shock, the planter deposits a cup of water and some fertilizer into the seedbed with each plant. If conditions are unusually dry, Abbett Farms may apply as little as 0.5" or as much as 1" of irrigation water through the pivot just ahead of planting to moisten and prepare the seedbed. From 10,000 to 13,000 tomato plants to the acre are used, depending on the variety. Planting begins in early May and continues into the middle of June. Harvest runs from late August through early October.

They have the capacity to apply 2" of water to the crop each week in two applications of 1" per pass in extremely dry weather. But for most of the growing season they apply about 1" of water a week. "It's supplemental, but essential," Glenn Abbett confirms. "We average only about 8"-10" of irrigation water a year through the pivot for tomatoes. That supplements the 3"-4" a month of rainfall we get during the summer months. Of course it all depends on how that rainfall arrives," he says. "If it all comes in a single storm, we'll be dependent on irrigation the rest of the month."

Because the tomato plant doesn't respond well to too much water, precise application of irrigation water is essential. "With too little water you're just wetting the plants and promoting disease. It's different with seed corn and other crops, where staying ahead of the crop's moisture need is more essential," Glenn Abbett suggests. "With tomatoes we try to let the seedbed dry out at times during the growing season to promote yields and prevent disease."

Later in the season, if rainfall is scarce, they apply 1" of water a week beginning as much as four weeks ahead of harvest to plump up the fruit and bring out the color. This also enhances uniformity of plant growth and fruit size at harvest. "We definitely use center pivots as a tool to 'size up' the tomato for optimum yield. We've done this successfully for many years, and the pivots are always ready when we need them. Our biggest problem is rainfall at the wrong time in the wrong amount," Glenn Abbett explains.

Since timing is critical, they spray an ethylene product on the crop two weeks ahead of harvest. "It's something the plant produces on it's own, but when you apply it 14-17 days ahead of harvest, it triggers the plant to produce more so that any green tomatoes ripen quickly on the vine and each plant's fruit ripens uniformly," he says.

Land-Grant Colleges and Universities (1862, 1890, and 1994)

Alabama A&M University
Normal, AL

Auburn University
Auburn, AL

Tuskegee University
Tuskegee, AL

University of Alaska
Fairbanks, AK

American Samoa Community College
Pago Pago, AS

Diné College
Tsaile, AZ

University of Arizona
Tucson, AZ

Tohono O'Odham Community
College, Sells, AZ

University of Arkansas
Fayetteville, AR

University of Arkansas Pine Bluff
Pine Bluff, AR

D-Q University
Davis, CA

University of California
System-Oakland as Headquarters
Oakland, California

Colorado State University
Fort Collins, CO

University of Connecticut
Storrs, CT

Delaware State University
Dover, DE

University of Delaware
Newark, DE

University of the District of Columbia
Washington, DC

Florida A&M University
Tallahassee, FL

University of Florida
Gainesville, FL

Fort Valley State University
Fort Valley, GA

University of Georgia
Athens, GA

University of Guam
Mangilao, GU

University of Hawaii
Honolulu, HI

University of Idaho
Moscow, ID

University of Illinois
Urbana, IL

Purdue University
West Lafayette, IN

Iowa State University
Ames, IA

Haskell Indian Nations University
Lawrence, KS

Kansas State University
Manhattan, KS

Kentucky State University
Frankfort, KY

University of Kentucky
Lexington, KY

Louisiana State University
Baton Rouge, LA

Southern University and A&M College
Baton Rouge, LA

University of Maine
Orono, ME

University of Maryland
College Park, MD

University of Maryland Eastern Shore
Princess Anne, MD

University of Massachusetts
Amherst, MA

Bay Mills Community College
Brimely, MI

Michigan State University
East Lansing, MI

Saginaw Chippewa Tribal College
MI

College of Micronesia
Kolonia, Pohnpei

Fond du Lac Tribal & Community College
Cloquet, MN

Leech Lake Tribal College
Cass Lake, MN

University of Minnesota
St. Paul, MN

White Earth Tribal and
Community College
Mahnomen, MN

Alcorn State University
Lorman, MS

Mississippi State University
Mississippi State, MS

Lincoln University
Jefferson City, MO

University of Missouri
Columbia, MO

Blackfeet Community College
Browning, MT

Chief Dull Knife College
Lame Deer, MT

Fort Belknap College
Harlem, MT

Fort Peck Community College
Poplar, MT

Little Big Horn College
Crow Agency, MT

Montana State University
Bozeman, MT

Salish Kootenai College
Pablo, MT

Stone Child College
Box Elder, MT

Little Priest Tribal College
Winnebago, NE

Nebraska Indian Community College
Winnebago, NE

University of Nebraska
Lincoln, NE

University of Nevada
Reno, NV

University of New Hampshire
Durham, NH

Rutgers University
New Brunswick, NJ

Crownpoint Institute of Technology
Crownpoint, NM

Institute of American Indian Arts
Sante Fe, NM

New Mexico State University
Las Cruces, NM

Southwestern Indian Polytechnic Institute
Albuquerque, NM

Cornell University
Ithaca, NY

North Carolina A&T State University
Greensboro, NC

North Carolina State University
Raleigh, NC

Fort Berthold Community College
New Town, ND

Cankdeska Cikana Community College
Fort Totten, ND

North Dakota State University
Fargo, ND

Sitting Bull College
Fort Yates, ND

Turtle Mountain Community College
Belcourt, ND

United Tribes Technical College
Bismarck, ND

Northern Marianas College
Saipan, CM

Ohio State University
Columbus, OH

Langston University
Langston, OK

Oklahoma State University
Stillwater, OK

Oregon State University
Corvallis, OR

Pennsylvania State University
University Park, PA

University of Puerto Rico
Mayaguez, PR

University of Rhode Island
Kingston, RI

Clemson University
Clemson, SC

South Carolina State University
Orangeburg, SC

Oglala Lakota College
Kyle, SD

Si Tanka College
Eagle Butte, SD

Sinte Gleska University
Rosebud, SD

Sisseton Wahpeton Community College
Sisseton, SD

South Dakota State University
Brookings, SD

Tennessee State University
Nashville, TN

University of Tennessee
Knoxville, TN

Prairie View A&M University
Prairie View, TX

Texas A&M University
College Station, TX

Utah State University
Logan, UT

University of Vermont
Burlington, VT

University of the Virgin Islands
St. Croix, VI

Virginia Polytechnic Institute and
State University
Blacksburg, VA

Virginia State University
Petersburg, VA

Northwest Indian College
Bellingham, WA

Washington State University
Pullman, WA

West Virginia State University
Institute, WV

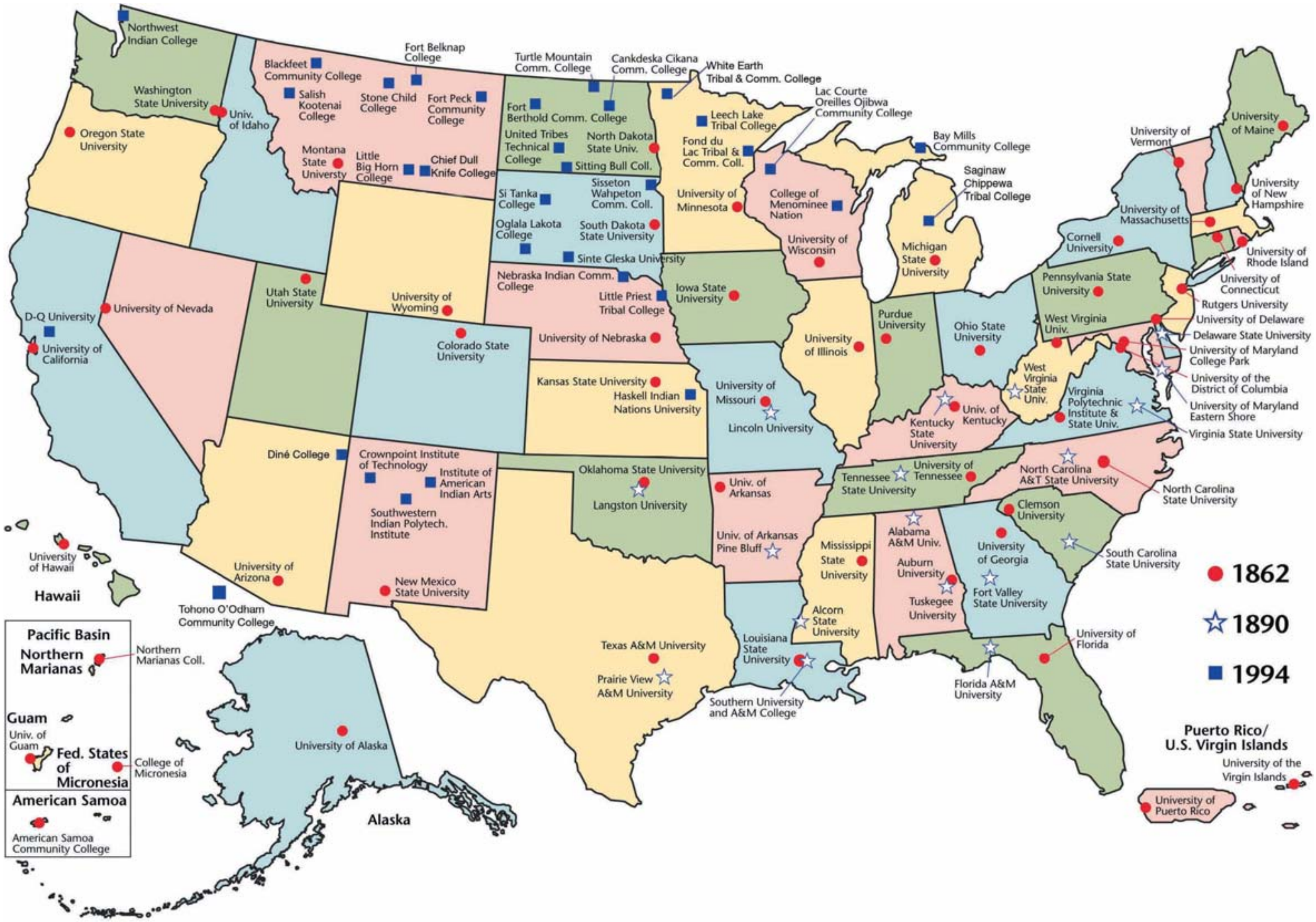
West Virginia University
Morgantown, WV

College of Menominee Nation
Keshena, WI

Lac Courte Oreilles Ojibwa
Community College
Hayward, WI

University of Wisconsin
Madison, WI

University of Wyoming
Laramie, WY


Northwest Indian College
Washington State University
Univ. of Idaho
Oregon State University
Blackfeet Community College
Salish Kootenai College
Stone Child College
Fort Belknap College
Fort Peck Community College
Montana State University
Little Big Horn College
Chief Dull Knife College
Turtle Mountain Comm. College
Cankdeska Cikana Comm. College
Fort Berthold Comm. College
United Tribes Technical College
North Dakota State Univ.
Sitting Bull Coll.
White Earth Tribal & Comm. College
Leech Lake Tribal College
Fond du Lac Tribal & Comm. Coll.
University of Minnesota
Lac Courte Oreilles Ojibwa Community College
College of Menominee Nation
University of Wisconsin
Bay Mills Community College
Saginaw Chippewa Tribal College
Michigan State University
Si Tanka College
Sisseton Wahpeton Comm. Coll.
Oglala Lakota College
South Dakota State University
Sinte Gleska University
Nebraska Indian Comm. College
Little Priest Tribal College
University of Nebraska
Iowa State University
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Cornell University
University of Vermont
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University of New Hampshire
University of Massachusetts
University of Rhode Island
University of Connecticut
Rutgers University
University of Delaware
Delaware State University
University of Maryland College Park
University of the District of Columbia
University of Maryland Eastern Shore
Virginia State University
West Virginia Univ.
West Virginia State Univ.
Virginia Polytechnic Institute & State Univ.
Kentucky State University
Univ. of Kentucky
Diné College
Crownpoint Institute of Technology
Institute of American Indian Arts
Southwestern Indian Polytech. Institute
New Mexico State University
Oklahoma State University
Langston University
Univ. of Arkansas
Univ. of Arkansas Pine Bluff
Tennessee State University
University of Tennessee
North Carolina A&T State University
North Carolina State University
Clemson University
South Carolina State University
Alabama A&M Univ.
Auburn University
Tuskegee University
University of Georgia
Fort Valley State University
Mississippi State University
Alcorn State University
Louisiana State University
Southern University and A&M College
Texas A&M University
Prairie View A&M University
University of Arizona
Tohono O'Odham Community College
University of Florida
Florida A&M University
University of Hawaii
Hawaii
Pacific Basin
Northern Marianas
Northern Marianas Coll.
Guam
Univ. of Guam
Fed. States of Micronesia
College of Micronesia
American Samoa
American Samoa Community College
University of Alaska
Alaska
Puerto Rico/ U.S. Virgin Islands
University of the Virgin Islands
University of Puerto Rico
1862
1890
1994