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PILOT IRRIGATION MANAGEMENT INFORMATION SYSTEM FOR THE CHO VALLEY

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EXECUTIVE SUMMARY

In 2003, work was concentrated in Kyrghyzstan, and the following was accomplished:

1. Second automatic weather station equipped with CR10X datalogger (Campbell Scientific, Inc.) was installed and activated in Soculuk agricultural area (32 km to the west of Bishkek; the first one is located 30 km to the east from the capital). The meteorological stations were equipped with solar radiation, temperature, relative humidity, and wind speed sensors. Three soil moisture sensors were connected to the datalogger with a multiplexer.
2. Three small weighing lysimeters, installed in the field in 2002, were used to determine water balance of winter wheat.
3. Remotely interrogated data from the two stations and weights of lysimeters were received at the IMIS center at the KSRII. Potential evapotranspiration (PET) was calculated by a CIMIS type Penman equation, measured hourly and summed over daylight hours, from global radiation, air temperature, relative humidity and wind speed. Actual ET was determined by soil water content changes in the weighing lysimeters.
4. Irrigation commenced on 13/05 and ended on 24/06; the quantity of water for irrigation was determined according to calculated daytime PET. Beginning April, soil water potential in the field was also monitored with WATERMARK sensors.
5. Dr. J. Tsipris traveled to Kyrghyzstan at May 2003 and participated in the location selection for the second meteorological station, in analysis of possible sources of errors in PET calculation and in operations of the field experiment. The data were processed in the winter months by Kyrghyz and Israeli teams.
6. According to results of two seasons, the daylight PET method provides reasonable estimate of PET for irrigation scheduling in the Cho Valley conditions.
7. IMIS information dissemination methods were tested.

For the 2004 irrigation season the following is planned:

- The installed weather stations and lysimeters will be used to continue field experiment with sorghum and alfalfa in Kyrghyzstan at the same locations, using the same experimental design and methods.
- Actual ET will be determined by soil water content changes in the weighing lysimeters; soil water potential will be monitored with WATERMARK sensors in the field experiment.
- Canopy cover and LI data will be collected to complement experimental results.
- The second weather station at Soculuk agricultural area will provide information to the surrounding farms.
- The IMIS software with Russian language outputs (E-mail document, faxes) will be completed.
- The IMIS will be operational on line for the currently covered area.
- The Impact of the IMIS on farm management and general water consumption will be evaluated.

Section I.

A. Research Objectives.

The aim of the program is to introduce a pilot Irrigation Management Information Service, similar to the Israeli one, adapted to Kyrghyz conditions, to fill the void in knowledge support generated by the agrarian reform.

Specific objectives of the program are:

1. Test and validate the scheduling algorithms and calibration parameters, against actual water use of main field crops.
2. Create a pilot IMIS, introduce it to the new extension organs, and analyze the response of the farmers.
3. Evaluate the efficiency of the hourly calculated, day-light time summed, modified Penman algorithm.

B. Research Accomplishments.

B.1 Equipment installation and testing.

In June 2003, the second automatic weather station (Campbell Scientific, Inc.) was installed in Soculuk agricultural area (32 km to the west of Bishkek). In addition to usual meteorological sensors (pyranometer, air temperature and RH probe, wind monitor and rain gage), three soil moisture sensors were connected to datalogger by AM416 relay multiplexer. This weather station functioned from 16/06 till 20/07/2003; the basic weather station (located 30 km to the east from the Bishkek, near experimental field) operated from 1/04 till 20/07/2003.

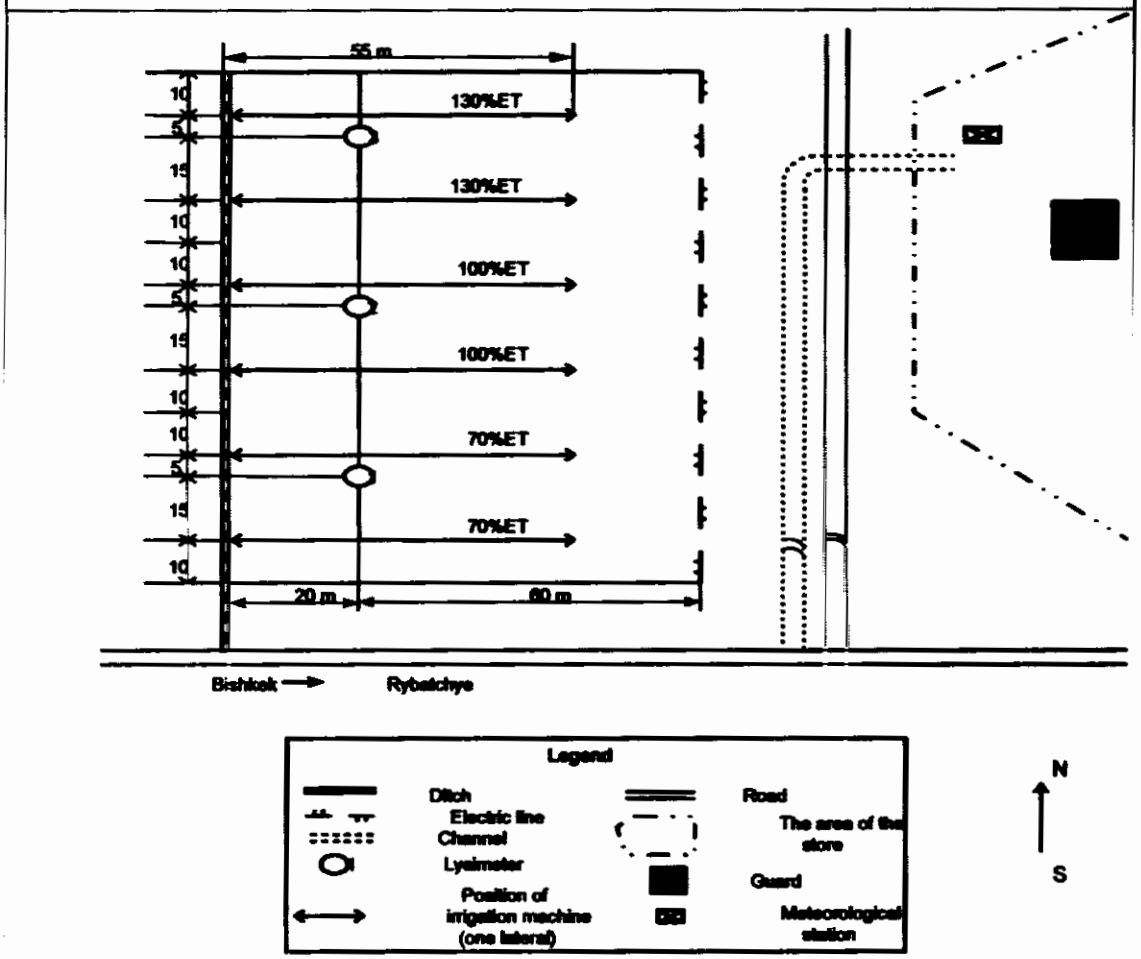
B.2 Field experiments - Materials and Methods

In 2003, an experiment was continued at Kant Machine Irrigation Station (MIS) near Bishkek, in the Chu Valley, Kyrghyzstan. Area of experimental plot was 0.96 ha (120 x 80 m), scheme in Fig. 1. Three lysimeters were installed and filled with soil on 3-5/04/2002 . Each lysimeter bin was 0.65 m in diameter and 0.8 m deep container. The total weight of the lysimeter filled with soil was near 500 kg. The lysimeter bin was hanged free inside of the outer container and leaned on three TEDEA 3411 Shear Beam Load Cells. The three load cells were connected in parallel to a Campbell Scientific 23X datalogger. Outputs were recorded every 6 seconds and processed through a 1/10 low pass filter to reduce environmental noise, and to increase the resolution. The weight W of lysimeter is a linear function of the voltage output V from the load cell:

$$W = a * V + b,$$

where a and b – coefficients ('a' was defined in the process of calibration).

Figure 1. Experimental site at Kant Machine Irrigation Station MIS), Kyrghyzstan



Weight calibration procedure was performed at 29/04/2003, and results were in good agreement with those obtained from calibration in 2002 (see Tab. 1).

Table 1. Coefficient 'a' defined in 2002 and 2003 from a weight calibration procedure.

Year	Lysimeter 1	Lysimeter 2	Lysimeter 3
2002	478.5	480.8	472.8
2003	484.6	491.8	477.5
Difference, %	1.3	2.3	1.2

The last calibration was used in 2003 data processing.

Irrigation was scheduled according to potential evapotranspiration (PET) with up and down bracketing (70%, 100% and 130% of PET, three treatments).

Irrigation amounts were calculated from hourly meteorological data by a modified Penman formula:

$$ET = \gamma/(\gamma+\Delta) * R_n *3600/latent + VPD*f(w) * \Delta/(\gamma+\Delta), \qquad (1)$$

where:

ET	Potential evapotranspiration, mm/hour;
R_n	Net radiation, W/m², calculated from global radiation;
VPD	Vapor pressure deficit (kPa);
γ	psychrometric constant (kPa/°C);
Δ	Slope of saturated vapor pressure curve (kPa/°C);
w	Wind speed (m/s);
f(w)	wind function, 0.034+0.054*w for daytime or 0.125+0.382*w for night;
latent	Specific vaporization heat (J/kg).

To measure the necessary variables for ET calculation (radiation, air temperature, relative humidity and wind speed), the first automatic weather station was assembled and deployed near the experimental farm, and the second station in Soculuk agricultural area (32 km to the west of Bishkek). Weather stations were equipped with the following sensors:

LI200X Pyranometer
CS500 Temperature and Relative Humidity Probe
RM Young 03001 Wind Sentry
TE525 Tipping Bucket Rain Gage.

Data processing was done on a PC, with Campbell PC208W data processing software and additional software and routines developed by the Kyrghyz team under the program while staying in Israel.
On 26/09/2002, winter wheat was sowed in the field and lysimeters. After winter 2002 -2003 conservation, lysimeters were prepared for measurements. Their preliminary calibration was done on 5/04/2003 together with draining the superfluous water from lysimeters ##1,2. In the period of 5/04-29/04, 80 mm rain fell, so it was necessary to drain water from lysimeters twice, on 22/04 and 29/04. The first irrigation in lysimeters was performed on 13/05 manually. Field and lysimeter irrigation was intended using a traveling lateral sprinkler system but manual irrigation was done for two reasons: First, the lysimeters water content was inadequate in the first stage of vegetation because the field irrigation was delayed due to high ground water level (but drained in the lysimeters). Ground water depth was approximately 1 m on 29/04 (see fig. 11); Second, the traveling irrigation system was not ready on time. To prevent damage to the crop in the lysimeters, it was decided to add water to the lysimeters until the irrigation system will be ready. Irrigation scheduling of lysimeters is shown in table 2 and the experimental plots - in table 3. On 25/05, only small amounts were added in anticipation for machine irrigation, on 31/05 and 18/06 lysimeter #3 was drained from excess water.

Table 2. Irrigation scheduling in lysimeters. MIS, Kyrghyzstan, 2003

Date	Irrigation, liter / mm(*)			Comments
	Lys #1 (70% ET)	Lys #2 (100% ET)	Lys #3 (130% ET)	
13/05		5 / 15	5 /15	Manually
17/05	10 / 30	15 / 45	20 / 60	Manually
21/05	13 / 39	12 / 36	16 / 48	Manually
25/05	4 / 12	2 / 6	2 / 6	Manually
28/05	7 / 21	10 / 30	13 / 39	Irrigation system(**)
31/05			-5.5/-16.5	Drain
08/06	7 / 21	13/39	24/72	Irrigation system
11/06	10 / 30	15 / 45	10 / 30	Manually
18/06	13 / 39	20 / 60	19 / 57	Manually
18/06			-8.5/-25.5	Drain
24/06	10/30	9/27	15/45	Irrigation system
total	**74/222**	**101/303**	**110/330**	

(*) calculated on basis of the inner drum surface area from manually added water volume.
(**) liters added calculated on basis of the inner drum surface area from irrigation depth.

Table 3. Irrigation scheduling in field plots near lysimeters. MIS, Kyrghyzstan, 2003

Date	Irrigation, mm			Comments
	70% ET	100% ET	130% ET	
28/05	21	30	39	
08/06	21	39	72	Lysimeters ## 2,3 were over irrigated
24/06	30	27	45	
total	**72**	**96**	**156**	

The last irrigation was performed on 24/06, and the crop was harvested on 19/07/2003

B.3 Field experiments - Results and Discussion.

Meteorological Measurements.

The weather station in Soculuk operated well and properly from its re-installation (16/06/2003) to the end of the season. There was a problem with power supply of Kant weather station, so datalogger and communication devices were connected to power circuit by converter 220VAC/12VDC on 29/04/2003. A brief description of the representative meteorological conditions in two sites is given in figures 2, 3, 4, and 5. The differences between air temperature and relative humidity of two meteorological station were not considerable in the period of simultaneous work. Stable average temperature transition of the 10° C line was observed on 04/05; from this date, average air temperature varied between 10.8° C and 26.7° C, and 38° C was the maximum of air temperature. RH average was above 45% in June-July. The place of Kant weather station is windier: daily average of wind did not exceed a value of 1.3 m/s in Soculuk against to 3 m/s in Kant in June-July. Global radiation was 10.4-31.0 MJ/m^2 for Kant and 12.5-32.9 MJ/m^2 for Soculuk.

Radiation drops below 25 MJ/m^2 indicate partly cloudy days. The comparison of hourly global radiation of two stations for a sunny day (Fig. 6) revealed the pyranometer of Kant was partly shaded in the afternoon hours from rapidly expanded tree. It was impossible to eliminate this artifact in 2003. The error of determination of global radiation was about 10% for sunny days at

Figure 2. Average Air Temperatures at Kant and Soculuk MS, Kyrghyzstan, 2003.

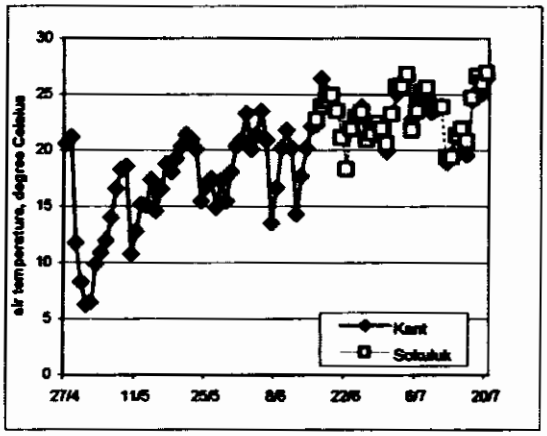


Figure 3. Average Relative Humidity at Kant and Soculuk MS, Kyrghyzstan, 2003.

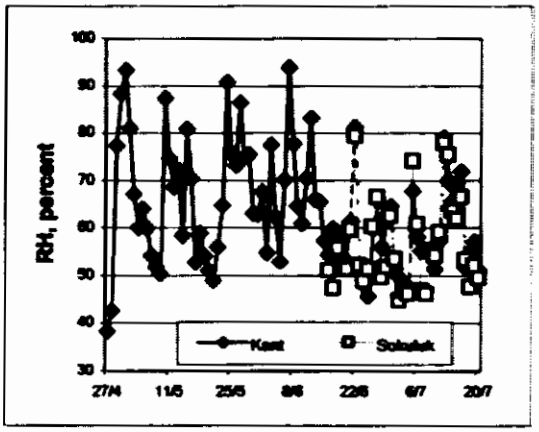


Figure 4. Average wind speed at Kant and Soculuk MS, Kyrghyzstan, 2003.

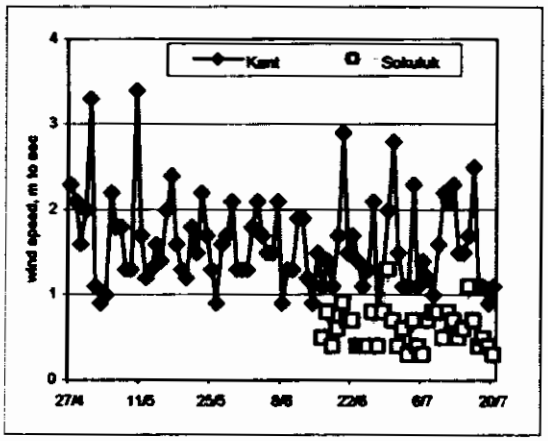


Figure 5. Global Radiation at Kant and Soculuk MS, Kyrghyzstan, 2003.

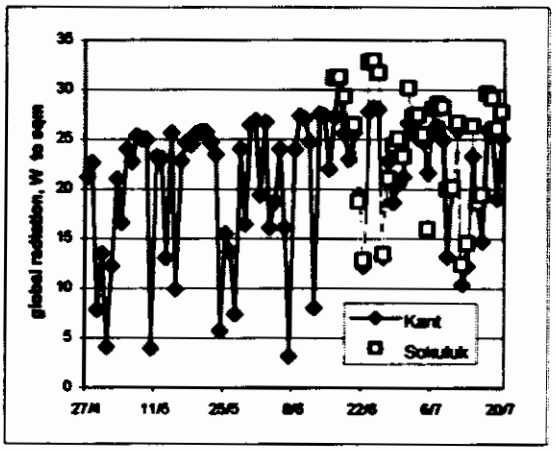


Figure 6. Hourly Global Radiation at Kant and Soculuk on 17/06, Kyrghyzstan, 2003.

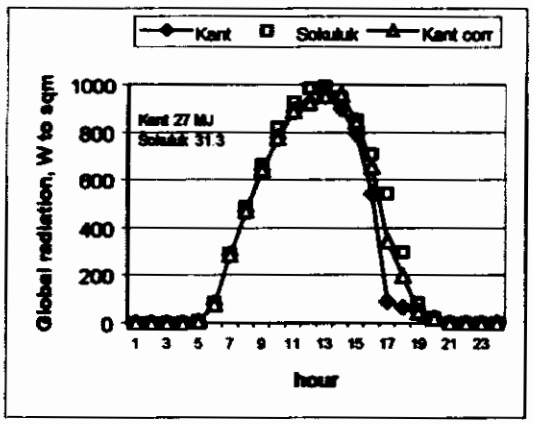
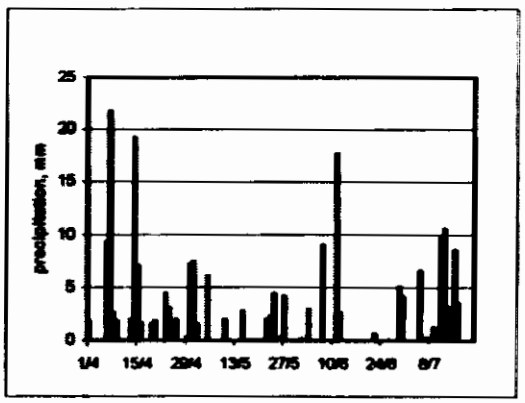


Figure 7. Daily Precipitation at Kant MS, Kyrghyzstan, 2003.



Kant weather station. Precipitation amounted to 95 mm in March and to 120 mm in the period from the beginning of water balance calculation (1/05) till 20/07/2003.

Evapotranspiration from lysimeters

Potential daytime ET for fully covered, well watered reference crop calculated by formula (1) ranged between 1.9 to 7.6 mm per day (compared to 3.2 – 7.2 mm in 2002) considering only days with rain less than 2 mm. Averaged value of PET was 5.36 mm compared to 6.05 mm in 2002 maybe because of pyranometer of Kant partial shading. In April, the water regime of lysimeters was influenced by spring rains and low ET to 30/04. The soil in lysimeters was wet, so two drainage pumping were performed in April. Water balance calculation began on 01/04. The amount of cumulative precipitation and PET were the same on 9/05, the first irrigation was given on 13/05 (only to lysimeters #2 and #3), and the last on 24/06. Daily course of cumulative sum of irrigation and rain *versus* cumulative PET (with 10% correction for partial pyranometer shading) calculated by Penman is given in Fig. 8. From 8/06 on the line of irrigation + precipitation goes above the PET line for lysimeters ## 2, 3 because of over irrigation done on this day by the lateral sprinkler system (see Table 3).

Figure 8. Daylight cumulative PET, irrigation and precipitation for lysimeters in mm (ET based on inner drum diameter).

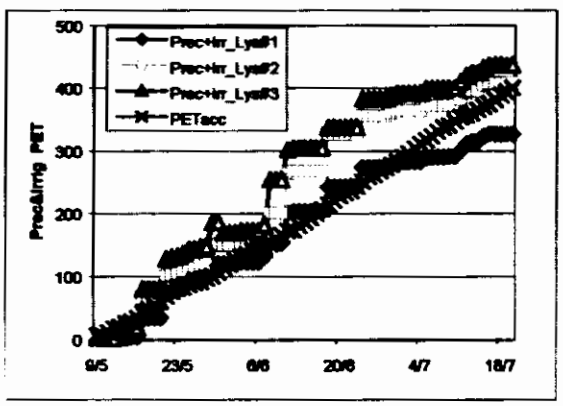
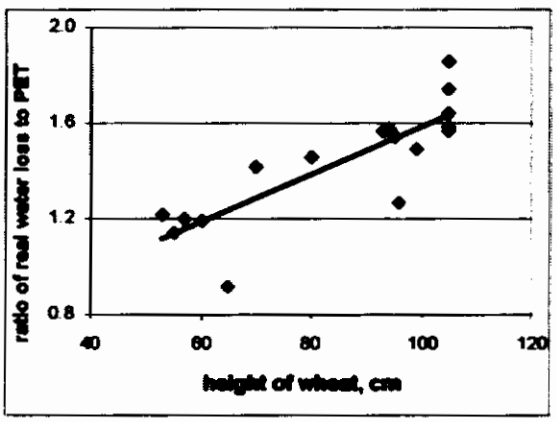


Figure 9. Water loss from lysimeter #2 (uncorrected for diameter) exceeding calculated ET vs height of wheat



Main components of lysimeters water balance are given in Table 4 for the period from 9/05 (equilibrium state of soil in lysimeters at field capacity) to 20/07 (harvest). Apparent ET of the control lysimeter (# 2) exceeded the calculated value of PET by 63 mm or 16%.

ET/irrigation depth to lysimeter weight transition and *vice versa* was performed during the experiment on nominal surface area basis of 0.3318 m^2 of the inner container of lysimeter.

In the 2002 season we recalculated the effective diameter in an interactive procedure of fitting calculated PET to actual lysimeters water balance, and found that the effective diameter was

Table 4. Water balance in lysimeters in period from 9/05/ till 20/07, Kyrghyzstan, 2003

	Lys # 1	Lys # 2	Lys # 3
Change in weight ($W=W_0 - W_t$), mm	41	63	-6
Irrigation (I), mm	219	296	330
Precipitation (P), mm	105	105	105
Drainage (D), mm	-	-	42
ET as part of water balance, no correction	365	464	387
Daylight PET (weather station)	401	401	401
ET after 16% correction for vegetation gap	315	400	334

0.70 m, about half the gap between the inner and the outer containers. That provides an effective evaporative surface of 1.16 times the inner container. After applying the same coefficient, the calculated and actual accumulated PET values in the control treatment (Table 4) corresponds well, reassuring the initial calculation.

Vegetative observations

Plant heights in lysimeters (Figure 10) and in field were about 20 cm in early spring. Only little difference was observed between field and lysimeters grown wheat canopy height till 11/5. After that, wheat in the field became 5-10 cm higher than in lysimeters.

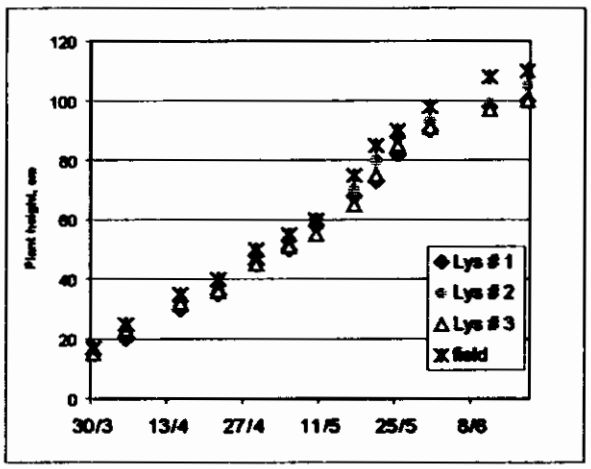


Figure 10. Plant height measurements, Kant MIS, Kyrghyzstan 2003

At May 9, when calculation of PET was started for water management use, the canopy height reached about 0.5 m and continued to grow. Because of operational problems with the Ceptometer inherited from a former CAR project, determination of actual light interception was difficult. From 50 cm crop height on, full crop cover was considered for PET evaluation.

The ratio of actual ET to calculated PET for selected 17 days with global radiation greater than 25 MJ, without irrigation and rains is presented against crop height in Fig. 9. There relation between the two is due to increasing LAI (Leaf Area Index) and the consequent radiation interception (which could not be measured this year), but also due to the effective transpiration area increase with wheat growth in lysimeter because of gaps in wheat growth around the lysimeter.

Soil water potential.

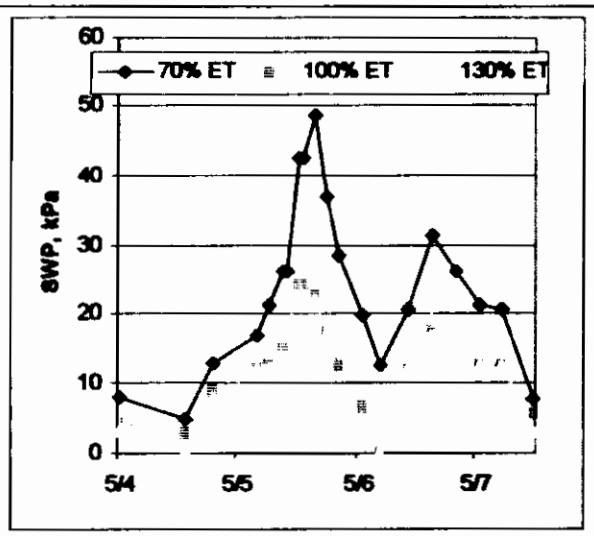


Figure 11. Soil Water Potential in the field at 30 cm depth, Kant, Kyrghyzstan 2003

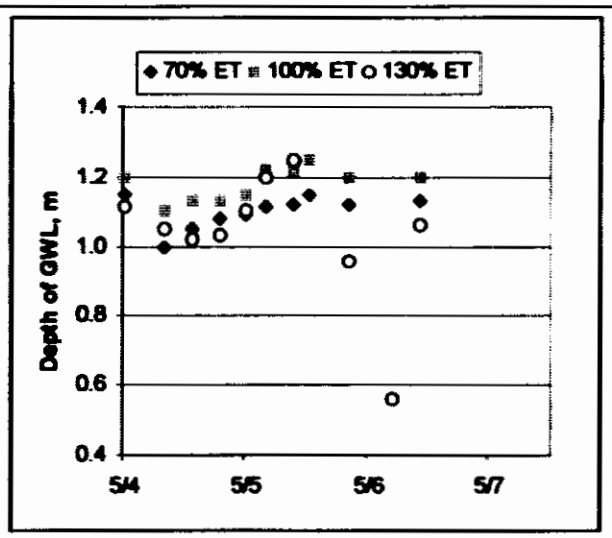


Figure 12. Depth of Ground Water Level < 1.3 m from soil surface, Kant, Kyrghyzstan 2003

Soil water potential (SWP) in the field was measured by two granular matrix soil moisture sensors ("Watermark", Irrometer Co., Riverside, CA) installed at 30 and 70-cm depth in four replicates for each irrigation treatment on 7/04/2003, at begin of the season. The Watermarks were installed along the line near the lysimeters at distance of 3, 6, 9, and 12 m in the field.

Soil water potentials measured at 0.3 m depth are shown in Figure 11. The course of SWP with time is non conventional, as it is not clearly following the usual saw tooth pattern of drying down and re-wetting after irrigation, partly because of sparse measurement intervals. Analysis of SWP at 0.3 m depth shows that only the 70% ET irrigation was under irrigated in the week of 21-28/5, assuming optimal soil water potential limit at 25-30 kPa. In the two other plots, SWP was all the season within the optimum.

Soil water potentials at 0.7 m depth (not shown) remained at very low values: 4.9, 1.5, and 0.6 kPa for 70%, 100% and 130% ET irrigation respectively, indicating saturated soil at that depth.

Groundwater depth in the field was about 1.0 – 1.2 m all the time from begin of the experiment to the end (Fig. 12). A flooding event from a neighborly irrigated field caused extremely wet conditions in the 130% ET irrigation treatment between 31/5 to 18/6.

Yields, water use and PET.

The yields in the lysimeters (Figure 13) peaked with 100% PET irrigation, with a small loss at 70% PET. The minute yield difference may be explained by the fact that only from the end of June lysimeter #1 was irrigated below PET (see Fig. 8). Grain yield in lysimeter #3 was significantly smaller probably because of the heavy over wetting. Wheat yields in the field, (mean of four replicates harvested in the plot) followed the water amounts applied according to the treatments.

Yields responses to applied water amounts (Figure 14) display a typical water response curve, the yields flattening out at ~300 mm and decline beyond 450 mm. That corresponds well with the 400 mm daylight PET derived from weather data over the main growing period. Applied water amounts in Figure 14 included irrigation and rain, but assumed that excess water was either drained down naturally or by pumping from the lysimeter, thus excluded from the water balance.

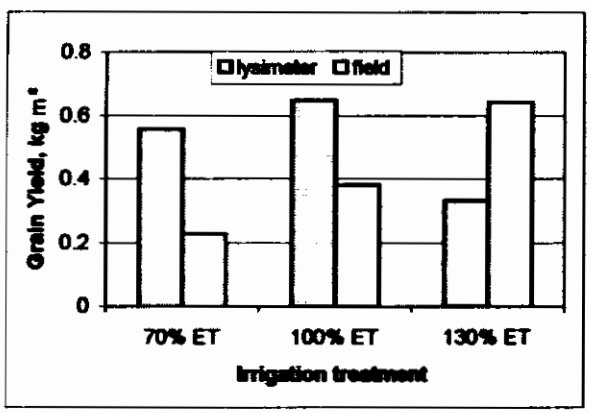


Figure 13. Grain yields in the field and the lysimeters, Kant farm, Kyrghyzstan 2003.

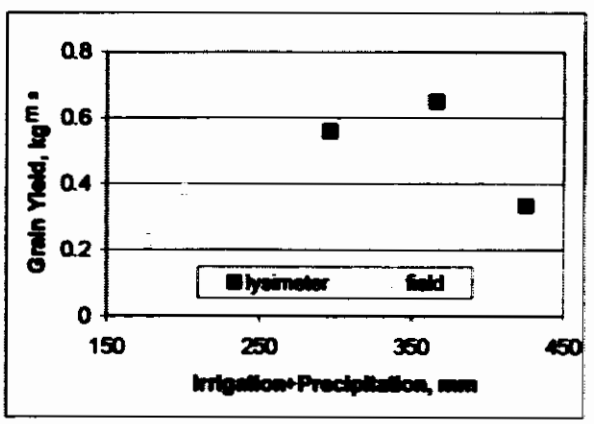


Figure 14. Water use efficiency in the field and the lysimeters, Kant farm Kyrghyzstan 2003

Data handling and report generation.

The software components for weather stations remote data acquisition, storage and processing were developed and tested during the stay of Dr. Litvak in MIGAL in 2001. They were used along the field experiment for irrigation scheduling and lysimeter performance evaluation. Both weather stations at KANT and Soculuk where remotely interrogated daily via tele-communication at the KSRII IMIS center.

Final formats for irrigation scheduling information management, with Russian language outputs, were developed and initial dissemination tests were performed. Routine dissemination will commence at the irrigation season of 2004.

Summary and Conclusions

- Two automatic meteorological stations were successfully operated in the Cho Valley, Kyrghyzstan, in the 2003 season, including remote data acquisition and processing in the IMIS center.
- Calculated daylight PET at 100% light interception for 62 days in the main growing season was 400 mm, (6.45 mm/day) and corresponded well to the ET part of the water balance in the control (100% PET irrigated) Lysimeter.
- Winter wheat yield response curves flattened out around 300 mm and declined after 400 mm irrigation & rain applied in the main growing season, disregarding drainage losses or water uptake from elevated ground water sources.
- Information dissemination methods were initially tested, and the IMIS will go into routine use at 2004.

C. Scientific impact of collaboration:

1. Initial impact of the collaboration is the mutual familiarization with scientific abilities of both sides and proper definition of objectives and goals to achieve though the project.

2. Introduction of state of the art irrigation scheduling methods for field crops to Kyrghyz agronomy.

3. Verification of the meteorological ET estimation model under high altitude - intermittent rainy conditions.

D. Description of Project Impact

1. The reports of IMIS introduced in frame of this project were given on following conferences:

   1. Principles and approach to activity of Water User Associations (WUA) in Republic of Kyrghyzstan. September 23, 2003. Bishkek

   2. Water Resources Problems. Round-table discussion in frame of Month of Science and International Year of Sweet Water. October 21, 2003. Bishkek.

2. Report: "System of automatized determination of irrigation rate and term for farmers" by M. Meron, J. Tsipris (MIGAL, Israel), R. Litvak, E. Nemaltseva (KSRII) (in Russian) was submitted to VI All-Russian Hydrologic Congress.

E. Strengthening of Developing Country Institutions

- Scientist from the KSRII spent a period of knowledge exchange in MIGAL.
- The KSRII team was exposed to hands-on operation of advanced environmental and irrigation research equipment and learned to use it in real life situations at home.
- The KSRII was enriched with advanced equipment, strengthening local research capabilities.
- The KSRII team gained experience in remote data collection and technology under local conditions.

F. Future Work

Work in 2004 will continue in Kyrghyzstan. The weather station and lysimeters assembled at MIS will be functioned to extend the results of 2002-2003 with different crops – sorghum and alfalfa. Irrigation will be applied according to calculated daylight PET with up and down bracketing (70%, 100% and 130% of PET) in field experiment and lysimeters using traveling lateral sprinkler system in field.

A second weather station will be functional at Soculuk agricultural area to provide information to the surrounding farms. The automatic data acquisition, processing and distribution software, developed in collaboration with MIGAL will be implemented. The final form of information dissemination will be designed and applied. E-mail document for farmers

and faxes for regional Water Management Administration will be disseminated in irrigation season of 2004. Final report will be prepared.

SECTION II.

A. Managerial Issues

In March-April 2003, the meteorological station and lysimeters at Kant Experimental Station were prepared to new field season. Two calibrations of lysimeters were performed in April 2003; 12 Watermark sensors were installed in the field. Field experiment included manual irrigation of lysimeters (to prevent plant water stress) and by the lateral sprinkler system, soil water potential measurements, and height of vegetation and crop yield determination. Second automatic weather station equipped with CR10X datalogger (Campbell Scientific, Inc.) was installed and activated in Soculuk agricultural area (32 km to the west of Bishkek) in June 2003.

B. Budget

All the budget items were spent according to the original work plan. The new instructions of quarterly expense reports and advance disbursement were implemented.

Financial reports were submitted periodically by MIGAL GM, Mr. J. Arzi.

C. Special concerns

No special concerns arise from beginning of the project.

D. Collaboration, Travel and Training

Israeli PI's Dr. J. Tsipris visited Kyrghyzstan in May 2003 for eight days.

Achievements: During this period he participated in choice of location for the second meteorological station, assisted in analysis of possible sources of error by PET calculation and partly in operation of the field experiment.

All the correspondence and ongoing technical and scientific support is carried out by Dr.Tsipris remotely from MIGAL.

Kyrghyz PI's and team:

The Kyrghyz staff of the project is now complete, consisting of Dr. R. Litvak (co-PI), and research assistants E. Nemaltzeva and I. Poddubnaya. The permanent staff of the Kant Machine Experimental Station provides technical assistance on site.

E-mail: An electronic mail link was established through the account of Dr. R. Litvak in the KSRII. This link enables fast exchange of written material in all the common formats.