WARMAP2

Water Resources Management and Agricultural Production in the Central Asian Republics

EC-IFAS

Executive Committee
Interstate Fund for the Aral Sea

IMPROVING THE PRODUCTIVITY OF IRRIGATION WATER IN CENTRAL ASIA

TRAINING MANUAL FOR SEMINAR

Tashkent March 1999

1. BACKGROUND

Since 1996, WUFMAS has been measuring the actual use of production inputs in 360 sample fields and the resulting crop yields. Data have been entered to the WUFMAS database, summarised and analysed in the Annual Reports. From these analyses, it is possible to give recommendations to the participating farms on how to improve the management of their resources and increase their profitability. It is proposed to go further than this on a small selection of fields in 1999 and for WUFMAS field staff to supervise the field demonstration of these improvements.

2. RATIONALE

There is urgent need in Central Asia to increase crop production while reducing water consumption. Lack of financial resources limits the investment opportunities so the scope for increasing production depends mainly on improvements in the standard husbandry and particularly in the scheduling of irrigation. Increasing the frequency of irrigation implies increased water consumption and is incompatible with water saving unless extreme measures are taken to improve the management of water.

The aim is to improve the productivity of water. There are different indices of productivity but the most widely used is physical productivity, measured in tonnes of crop product per thousand cubic metres of water used for irrigation (t/tcm). This index alternatively can be increased by (a) saving water while keeping yield constant, (b) increasing yield while keeping water use constant, and (c) by both saving water and increasing yield together. Since water, other inputs, and different crop products do not have the same unit price, the economically most favourable alternative cannot be judged from this simple index.

The basis of the economic indices is the **gross margin**, “profitability” before deduction of farm overhead costs. It may be expressed in terms of gross margin per unit of water used ($/tcm) or better still, as a return on investment in the water used, gross margin per unit cost of water ($/$). Gross margin takes no account of leaching water because only water used for irrigation is a truly variable cost as fields may need to be leached whatever crop is grown. However, water saving is likely to reduce discharge to the groundwater and watertables may fall, reducing the severity of secondary salinisation and the need for leaching.

The drawback to using an economic index is that in centralised economies (Turkmenistan and Uzbekistan) the prices at the “farm gate” (financial prices) are quite different from those that would exist were the economy open to the world market without Government intervention (economic prices).

As a guide to selection of the most favourable strategy, it is possible to simulate a number of scenarios as variations based on the current average budget for cotton. This is shown in Table 1.

Table 1 Analysis of Alternative Scenarios for Improving Water Productivity

Item	Units	Scenario **1 (1)**	Scenario **2**	Scenario **3**	Scenario **4**	Scenario **5**	Scenario **6**	Scenario **7**
Prices		Financial	***Economic***	***Economic***	***Economic***	***Economic***	***Economic***	Financial
Proposed changes to:								
Yield		Present	Present	Present	Increase	Increase	Increase	Increase
Agronomy		Present	Present	Present	***Improve***	Present	***Improve***	***Improve***
Production cost		Present	Present	***Reduce***	Increase	Increase	Increase	Increase
Irrigation schedule		Present	Present	Present	Present	***Improve***	***Improve***	***Improve***
Irrigation water		Present	Present	***Reduce***	Present	Present	***Reduce***	***Reduce***
Leaching water		Present	Present	***Reduce***	Present	Present	***Reduce***	***Reduce***
Gross Margin Analysis:								
Yield	t/ha	2.3	2.3	2.3	3.5	3.5	4.0	4.0
Price	$/t	378	480	480	480	480	480	378
Gross output	$/ha	869	1104	1104	1680	1680	1920	1512
Variable Costs:								
Seed	$/ha	28	28	28	28	28	28	28
Fertiliser	$/ha	54	95	95	143	95	143	81
Machinery	$/ha	172	206	206	215	215	220	185
Labour	$/ha	64	64	64	70	70	75	75
Agro-chem	$/ha	8	8	8	40	8	40	40
Water	$/ha	6	110	90	110	110	105	6
Total Variable Cost	$/ha	332	511	492	606	526	611	415
Gross Margin (GM)	$/ha	537	593	612	1074	1154	1309	1097
Water use:								
For irrigation	tcm/ha	7.3	7.3	6	7.3	7.3	7	7
For leaching	tcm/ha	4.6	4.6	2	4.6	4.6	2	2
Total water used	tcm/ha	11.9	11.9	8	11.9	11.9	9	9
Productivity of Water:								
Yield/unit of irrig water	t/tcm	0.32	0.32	0.38	0.48	0.48	0.57	0.57
Yield/unit of total water	t/tcm	0.19	0.19	0.29	0.29	0.29	0.44	0.44
GM/unit of irrig water	$/tcm	74	81	102	147	158	187	157
GM/unit of total water	$/tcm	45	50	77	90	97	145	122
GM/Inv't in irrig water	**$out/ $in**	**86**	**6**	**8**	**11**	**12**	**13**	**181**
GM/Inv't in total water	**$out/ $in**	**57**	**4**	**6**	**7**	**7**	**10**	**147**

Note (1): Data are average values for cotton in Central Asia (WUFMAS, 1997)

Scenario 1: The base case at financial prices, in which the rates of input and yield are the averages of 137 cotton fields studied by WUFMAS in 1997, and the prices are the average financial prices for all republics. The farmgate price of raw cotton is weighted by low values for Turkmenistan and Uzbekistan. Irrigation water produces 0.32t of cotton or a gross margin of $74 per thousand cubic metres used. Financial investment in water for irrigation yields a return of $86 per $ invested in water for the crop (8,600 percent), an excellent return for the farm but this takes no account of the massive state subsidies on the price of water.

Scenario 2: The same base case but using economic prices, the gross margin per unit of irrigation water is increased to $81/tcm. Due to the much greater economic price of water ($15 per tcm is assumed here), the economic productivity of water as a return to investment is very much reduced to only $6 per $ invested (600 percent) but nonetheless is very favourable. Even with the inclusion of leaching water, the return to investment in all water is 400 percent.

Scenario 3: The benefit of water saving alone is examined in this scenario at economic prices. Savings of 2.3tcm/ha for irrigation and 2.6tcm/ha for leaching are assumed, or 41 percent water saving overall and a reduction in total variable cost of 4 percent. Physical productivity increases to 0.38t and gross margin $102 per tcm of irrigation water, and the investment return to $8 per $ invested (800 percent). This may be a demonstrable scenario, but with the financial price of water so low and canal operators and irrigators having no particular incentive to achieve water saving, it is not likely to be sustainable.

Scenario 4: Improved general agronomy alone, without water saving or improved water management or scheduling, is examined here. It is assumed that yield could be increased to 3.5t/ha as a result of improved timeliness of operations, and reduced deficit of nutrients and competition from weeds and pests, with a 19 percent increase in the total variable cost of production. The improvement in the productivity of water is much greater than with water saving in scenario 3, and the return to investment in irrigation increases to $11 per $ invested (1,100 percent). It is unlikely that without cash incentives to farm staff, they would sustain the improvement in the level of management that is necessary to achieve this improvement, but part of the cash benefit could be used to provide an incentive and enhance the chance of sustainability.

Scenario 5: The benefit of improved scheduling of water is examined here, with the same amount of water being distributed over more frequent applications. Reducing the periodic water stress of the crop is assumed to increase yield to 3.5t/ha without other measures. The three- percent increase in total variable cost is due to the cost of harvesting the extra yield. The physical benefit is the same as in scenario 4 but the economic benefit is greater at $158 per tcm of irrigation. The return on investment in irrigation is $12 per $ invested (1,200 percent). This measure is likely to be more economically favourable than water saving and increasing yield by improved agronomy alone. However, without significant capital investment and improved management of the canal systems, and cash incentives to irrigators and canal operators, this scenario may not be achievable or sustainable.

Scenario 6: This ideal scenario examines the benefits of a big yield increase due to improved husbandry and water scheduling together, at the same time as a big improvement in application efficiency permits a small saving in water of 24 percent, mainly during leaching. The cost of producing this 74 percent extra yield is a 20 percent increase in the variable cost of production. The physical productivity of irrigation water increases by 78 percent to 0.57t/tcm but the gross margin by 231 percent to $187/tcm. There is however, only a modest further increase in the return to investment in irrigation to $13 per $ invested (1,300 percent). The same caveats to sustainability as above apply in this scenario.

Scenario 7: Financial prices used in the base case scenario are here applied to the improvements in management anticipated in scenario 6. The gross margin per unit of irrigation water is much less than when economic prices are used, but the heavy subsidy on water creates a massive improvement in the financial return to investment. The big yield increase to 4.0t/ha of raw cotton is worth an extra $390/ha in revenue from indirect taxation of cotton to the Governments of Turkmenistan and Uzbekistan.

Conclusion of Analysis

From the foregoing simulation, it appears that increasing yield is economically more advantageous than saving water. However, this analysis takes no account of the hidden costs of wastage of water, the massive costs of land drainage and leaching to control secondary salinity, or as at present with failure of the drainage systems, the costs of leaching, production lost from uncontrolled salinity and the abandonment of land. For these reasons, clearly the most favourable strategy for agricultural development is to promote yield increase from better crop husbandry and increased investment while significantly improving the efficiency of water management in the field and the canal system. Sustainability will depend on capital investment in the canal system and improved cash incentives to operators and farm staff.

3. PROPOSED IMPLEMENTATION PHASE - 1999

3.1 Objective of Proposal

To demonstrate and monitor the benefits of increasing the productivity of water by improving the management of farm resources, increasing crop yield by improved husbandry and irrigation scheduling, while saving water during the application of water in the field.

3.2 Programme for 1999

3.2.1 Preparation Stage 1:

1. Select one of each of the pairs of sample farms in the WUFMAS programme (2 farms in Kazakhstan, 2 farms in Kyrgyzstan, 1 farm in Tadjikistan, 1 farm in Turkmenistan, 6 farms in Uzbekistan).
2. Prepare the Participating Farm Reports for the 12 selected sample farms (as per Item 3, Form 1.4, Inception Report of WARMAP 2).
3. Modify the existing WUFMAS monitoring forms and the codebook where necessary, and introduce new forms appropriate to monitoring water application.
4. Prepare new guidelines to implementing the changes in water and crop management in the demonstration fields as a WUFMAS Demonstration Manual.

3.2.2. Training Seminar:

5. Organise a seminar in Tashkent for the 5 WUFMAS NWG co-ordinators and 12 supervisors who will be responsible for implementing the sub-project, to give detailed training on (a) how to improve the crop agronomy, (b) improved scheduling of irrigation (including the management of the supply canals to make this possible), (c) improved in-field water management to increase the efficiency of application and save water.

3.2.3 Preparation Stage 2:

6. The supervisor of each chosen sample farm with the RWG and NWG to select two adjacent sample fields, one as the Demonstration Field (DF) and the other as the Control (CTRL), and the RWG to visit the fields selected by the supervisors. The RWG to agree changes with Director and identify any investment that may be necessary by the project to ensure that the required changes will be fully implemented. (See outline in Annex 1.)
7. Make a field survey, sample soils and analyse samples to support agronomic and water management improvements.
8. Prepare an addendum to the farm report detailing the changes that are to be made in the demonstration field, and the monitoring programme for both fields.

3.2.4 Implementation Phase:

9. Supervisors to implement the programme of changes to be made in the DF from before sowing of the crop where possible. (See outline in Annex 2.)
10. Supervisors to complete the WUFMAS farm-level record sheets as in previous years, and to begin the monitoring as early as possible, but no later than planting of the crop, in both DF and CTRL fields using the previous and new field record sheets.
11. RWG and NWG members to make periodic visits to the fields during the season and check that guidelines are being implemented effectively, reasonable progress is being made and that monitoring is on schedule, returning record sheets to RWG premises.

12. RWG and NWG to organise a field day on each demonstration field for local MoA, Minvodkhoz and Hakimiyat staff to explain objectives.

3.2.5 Database, Analysis and Reporting Stage:

13. Data on record sheets to be entered into a new WUFMAS database, and RWG to make systematic analysis of the monitoring data at intervals.
14. Prepare a detailed 1999 Annual Report, including proposals for the year 2000 season.

3.2.6 Reporting Seminar:

15. Organise a seminar in each republic for MoA and WUFMAS staff, in order to present results in the 1999 season and discuss the continuation of the programme in year 2000.

3.3 Schedules and Staffing

The schedules and required staffing are shown in the following table:

Work and Staffing Schedule														
Programme	No	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total (mxm)
Stage 1 Prep. 1		xx	xxxx											
Stage 2 Trng Seminar				x										
Stage 3 Prep. 2			xxxx	xxxx	xxxx									
Stage 4 Implement'n.					xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx		
Stage 5 Data, Report						xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	xxxx	
Stage 6 Rptg Seminar													x	
Staffing (mxm)														
RWG	4	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	2.0	24.0
Other specialists	3			1.0	1.0	1.5	1.0	1.0	1.0	1.0			0.5	8.0
NWG	5		0.5	0.5	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.0	11.0
Surveyors	6			3.0	3.0									6.0
Supervisors	12		3.0	3.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	12.0	3.0	105.0
Enumerators	12				12.0	12.0	12.0	12.0	12.0	12.0	6.0	6.0		84.0
Assistants	24				36.0	36.0	36.0	36.0	36.0	36.0	18.0	18.0		252.0
Lab Staff	3				3.0	3.0								6.0
Database experts	2	1.0	1.5	1.5			2.0	2.0	2.0	2.0	2.0	2.0	2.0	18.0
Foreign consultant	2	0.2	0.5	0.5	0.5	0.5	0.5	0.8		0.5		1.0	1.0	6.0

3.4 Output from sub-project

The most important output of this proposal will be the value of demonstrating the potential to improve scheduling of irrigation and management of water in the field during irrigation. It is equally important to demonstrate that crop yield must increase hand-in-hand with better water management, and that initiatives are economically viable if improvements are to be sustainable in the long-term.

A detailed report will provide the analysis of the benefits in increased productivity of water and identify the likely constraints to future replication of the model on a wider scale. The two seminars proposed would give further valuable in-service training to key staff who have been working in the WUFMAS programme for 3 years. The field days on each of the demonstration fields will provide an insight into the key issues for development of the agricultural sector to local staff of the farm, the Hakimiyat and the Ministries.

4. SCOPE FOR INCREASING CROP YIELD AND EFFICENCY OF WATER USE

The WUFMAS 1997 Annual Report provides a summary of the wide variety of data collected on the sample farms, and begins the process of analysing the data. One outcome, was the conclusion that the main scope for increasing crop yield lies in the timeliness and effectiveness of husbandry operations rather than in large extra costs of production. This amounts to more sensitive husbandry of the natural resources and the crop:

1. Detection of the presence of a plough-pan or other indurated soil horizon and sub-soiling of the field prior to ploughing, and care over the soil moisture status during mechanical operations thereafter in order to avoid the re-appearance of such horizons;
2. Checking of surface soil salinity by portable EC meter prior to sowing, pre-plant leaching if the value is high and rehabilitation of field drains where necessary;
3. Rapid survey of the field to detect serious undulations that cause localised salinisation and make uniform irrigation impossible, and relevelling where this is considered economically justified;
4. Scientific modelling of water movement across the field using either local method or PUMA, and re-adjustment of furrow length, field length or basin size where necessary;
5. Management sensitivity to the importance of promoting the most rapid early growth of the crop, the deepest possible root system, and in cotton the retention of as many as possible of the first set bolls;
6. For row-crops, application of P fertiliser banded with the seed rather than broadcast and ploughed-in;
7. Where analysis indicates soil deficiency, addition of K fertiliser and somewhat more P fertiliser than at present, banded with the seed at planting, paid for in some cases by reduced application of N fertiliser;
8. More timely application of N fertiliser, with about 20kg N/ha at planting and for cotton, three sidedressings of about 30-40 kg N/ha together with inter-row cultivation, between 7June and mid-July in most areas;
9. Use of a post-planting, pre-emergence herbicide (or a post-emergence herbicide where necessary and possible) to minimise weed competition in the early stages of the crop;
10. Earlier thinning and gap-filling of row-crops, to minimise early competition between seedlings;
11. Scientific scheduling of irrigation using either local climate data in CROPWAT or data from an evaporimeter pan on the farm, making the necessary changes to the actual timing of irrigations to reduce the irrigation intervals and crop moisture stress;
12. Apply either local method or PUMA to establish the ideal furrow flow rate and duration of irrigation, and ensure that the number of furrows under simultaneous irrigation corresponds with the discharge rate to the field, and that irrigators cut-off furrow flows at the correct time;
13. A systematic schedule of pest “scouting” of crops to monitor the development of pest attack and guide an integrated pest management approach to pest control;
14. Use of low-volume application of modern, narrow-spectrum pesticides during the early stage of pest development (rather than the heavy doses necessary to control adult pests after damage is already serious).

5. OUTLINE OF MEASURES TO BE IMPLEMENTED IN THE FIELD

5.1 Field Survey of the Control and Demonstration Fields

5.1.1 Measure the dimensions of the field and make an accurate scale plan. Use the Abney level or a standard survey level with staff to measure the gradient along the line of furrow or irrigation flow and indicate areas of uniform slope, hillocks and depressions on the plan. Mark the approximate boundaries of any obvious changes in soil texture across the field.

5.1.2 Dig a pit, describe the profile, use the penetrometer at narrow intervals down the profile to record resistance to penetration, and take undisturbed soil cores at 25cm intervals down the profile. Take a composite topsoil sample from each field.

5.1.3 Insert lining tubes in augerholes in all five sample plots in Demonstration and CTRL field to measure depth of watertable. Take water samples for analysis.

5.1.4 Use the portable conductivity meter to measure pH and conductivity of top and subsoil at several points in the field before planting, and record areas of high salinity on plan. Measure the pH and conductivity of the topsoil and groundwater before and after irrigation throughout season.

5.1.5 Return soil cores, soil and water samples and in situ measurements to SANIIRI research laboratory for immediate measurement of soil texture, bulk density, moisture characteristics, available moisture capacity, and salinity.

5.1.6 Use double ring infiltrometer and constant head method to measure infiltration over at least 20 hours, and in triplicate in DF.

5.1.7 Run initial data for field through Local model and PUMA (software for optimising application efficiency by adjustments to furrow length, furrow flow rate and duration of irrigation) in order to check that existing furrows are close to optimal length.

5.2 Land Levelling and Preparation (in DF only)

5.2.1 Organise relevelling of the DF if this is technically and financially justified.

5.2.2 Organise ripping (subsoiling) of demonstration field to at least 0.5m deep at 0.9m intervals (before ploughing if possible). Ensure that soil moisture conditions are ideal at the time of operation.

5.2.3 From the conclusion of 1.7, if technically and financially justified, shorten (or lengthen) furrows and re-orientate them across the slope, or reduce field length or basin size.

5.3 Irrigation Scheduling (for DF only)

5.3.1 Use long-term climate data means and soil data to produce an average irrigation schedule by CROPWAT.

5.3.2 Make decad measurements of average crop rooting depth and height, and the depth of the watertable before and after irrigation, and estimate the crop coefficient.

5.3.3. Record daily evaporation from farm evaporimeter and rainfall, and keep a daily water balance using data from 1.5 and 3.2 in order to signal the day the field should be irrigated but with at least 3 days warning.

5.3.4. Use the “Quickdraw” tensiometer (QDT) at several points in the DF to maintain a daily log of soil moisture status taking occasional soil samples to measure moisture content gravimetrically in order check calibration of QDT. Compare schedules in 3.1 and 3.3 with QDT log with a view to verifying or adjusting the pan coefficient used in 3.3 and assumptions in 3.1.

5.3.5. Ensure that the crop is irrigated on the scheduled day. Measure the volume of water applied in the DF (see below) and calculate the application efficiency for each irrigation.

5.3.6. Repeat appropriate steps for the Control field except that it should be irrigated only according to established custom, uninfluenced by activities in the DF.

5.4 In-field Water Management (in DF only)

5.4.1 Immediately after making irrigation furrows, locate a site if possible in the DF, where the hydraulic head of the field canal over the furrow is sufficient to be able to measure the furrow flow rate using a Thompson weir. Mark and dam a representative 10m length of furrow, insert a calibrated peg at the centre point and estimate the soil moisture content using the QDT. Begin rapid discharge into the test furrow and into adjacent furrows, recording the furrow flow rate and the depth of water on the peg at recorded time intervals (one minute at start, later changing to 5 minutes, then 10 minutes, then 30 minutes). Record the time to fill the test furrow to the selected constant depth and measure the furrow shape characteristics. Once furrow is filled to selected depth, adjust flow rate over weir to maintain it until a constant infiltration rate has been achieved (at least 12 hours). From the plot of discharge against time, estimate the three Kostiakov-Lewis parameters for the site. Compare these estimates with those determined from 1.6.

5.4.2 Measure the maximum possible discharge rate of water into the field or flow rate in the field canals using the Cipoletti weirs. If seriously constrained by silting or weeds, organise the cleaning of the supply canal back to the off-take.

5.4.3 Measure the furrow shape and estimate the average furrow shape parameters. Repeat this activity before each irrigation.

5.4.4 Use field characteristics and scheduled net irrigation requirement in PUMA to optimise furrow flow rate and duration of irrigation prior to each irrigation. This may be done either by the NWG co-ordinators using PUMA in each republic or by telephoning data to the RWG.

5.4.5 Measure current flow rate in field canal and divide by the optimised furrow flow rate in order to establish the number of furrows to be simultaneously irrigated. Ensure that only this number of furrows is being irrigated and that the duration is strictly observed.

5.4.6 Mark sample furrows (say 5-10 across field). Place calibrated pegs at intervals of 10 percent of total furrow length and a Thompson weir at the top and bottom of the furrow. Record the time that the wetting front reaches each peg, the maximum depth reached and the time, and the time of recession.

5.4.7 Using PUMA to simulate the recorded water movement, work back to recalibrate the Kostiakov-Lewis parameters. Calculate the actual application efficiency and compare it with the target value. Calculate the actual irrigation efficiency in the control field in order to assess the effectiveness of the improvements.

5.4.8 Repeat these steps for each irrigation and, at the end of the season, make an overall assessment of the effectiveness of the measures taken.

5.5 Canal Monitoring

5.5.1 The project lacks the resources to rehabilitate the main distribution system (desilt canals, repair structures and install new ones).

5.5.2 A map of the farm canal system should be obtained and a survey made of current (a) cleanliness of the canals, (b) location and state of the control structures, (c) location and state of measuring devices.

5.5.3 Strategic monitoring points (MP) should be identified, 10m length of canal cleaned and sectional profile measured at each.

5.5.4 Measuring poles should be prepared and installed al MPs. A survey team should visit all farms in order to calibrate the canal flow at all MPs using the project flowmeters.

5.5.5 Prepare new records sheets in order to record daily delivery of water to the farm, flow rates at MPs, and information about the use of the water.

5.5.6 The annual report will contain a review of these data plus recommendations for improved management of the canals and estimates of the capital investment, institutional changes and training that are necessary.

5.6 Improvements to Crop Husbandry

5.6.1 The basis of the improved husbandry is the recommendations given in the participating farm report (PFR)

5.6.2 Ensure that P fertiliser is NOT broadcast and ploughed-in (except for crops with broadcast seed like grass, lucerne, rice) as this increases exposure of P to fixation by soil and reduces the efficiency of its absorption by the crop.

5.6.3 Use the portable conductivity meter to check that the salinity of the surface soil is less than 0.5dS/m. If not then make light ridges before planting and pre-irrigate in order to leach the ridge soil. Plant seeds into side of ridge.

5.6.4 Ensure that the seed to be planted is of suitable genetic quality and of adequate viability and uniformity, and if possible it is treated.

5.6.5 Ensure that soil conditions are good at time of planting, the planter is operating properly and is correctly set. Check seed depth and density immediately after planting begins, and adjust if necessary. Note that anthesis and pollination in some crops are seriously affected by high temperature and moisture stress and planting date and irrigation schedules should be adjusted accordingly (maize is particularly sensitive).

5.6.6 Ensure that the recommendations for planting fertiliser given in the PFR are understood, the correct N:P:K ratio of fertiliser is available for use at planting, the planter is equipped to side-band fertiliser with seed (except for broadcast crops), and that the fertiliser applicator is correctly calibrated. Check location of fertiliser band in relation to seed after planting, as this is critical in avoiding seedling damage by N and K fertilisers, and reducing P-fixation by the soil, and adjust machine if necessary.

5.6.7 Ensure that a suitable herbicide is available (normally but not exclusively it will be of the post-plant, pre-germination type) and that equipment is available to apply it in an appropriate manner. There may be tanks mounted on the tractor that supply herbicide by gravity through a “fish-tail” nozzle located over the press-wheel of the planter. Otherwise, arrange for application over the row by knapsack sprayer with a large-droplet nozzle. In the event of a granular herbicide being available, it may need to be applied through a fertiliser distributor and harrowed for incorporation with soil.

5.6.8 Monitor germination and early growth of seedlings with respect to moisture stress, soil capping, disease and pest damage, weed competition, and immediately after gaps in seedling rows are noticed, re-seed by hand. Take remedial measures where necessary in order to promote the most rapid possible early growth and development of the crop. High yield is dependent on this.

5.6.9 Ensure thinning of seedlings (and weeding in-row if herbicide was ineffective) at the earliest opportunity when the establishment of the seedlings is assured (ie there is no sign of further loss of seedlings from pests or disease). Check that final plant population is close to that recommended in the PFR.

5.6.10 Where post-germination application of herbicide is appropriate and necessary (eg in wheat and rice) ensure that this is done without delay so as to avoid competition and weeds setting their seeds.

5.6.11 Arrange for the first interrow cultivation of row crops as soon as seedlings are big enough to avoid being damaged, and particularly after heavy rain or the first irrigation has caused soil capping, and if there is significant weed growth in the interrow. If this is before late May/early June (depending on location) and before the onset of rapid vegetative growth then do not side-dress with N fertiliser. Interrow cultivation ideally should be done only AFTER irrigation (or heavy rain) and only when the soil has dried out sufficiently to avoid compaction from the wheels. The objectives are to (a) destroy weeds in the interrow before their competition reduces the growth rate of the crop, (b) to aerate the soil after capping by water, and (c) to reduce evaporation through the loose layer of soil (mulch), that breaks continuity for mass flow of water to the surface. Do NOT cultivate before irrigation, except where the soil is badly capped and the field gradient is too great to allow sufficiently rapid infiltration for improved application efficiency of water, and when nitrogen fertiliser is to be side-dressed at the time of interrow cultivation.

5.6.12 If the first interrow cultivation is after about 7 June (earlier in S Uzbekistan but later in N Kazakhstan and Kyrgyzstan), rapid vegetative growth will have started and the first side-dressing of N fertiliser should be applied prior to or concurrently with interrow cultivation. Repeated side-dressing of N fertiliser, with immediate incorporation or covering of the fertiliser by soil, are aimed at improving the absorption efficiency of this volatile and soluble fertiliser, making possible a reduction of overall rate. With broadcast crops (or narrow rows), N fertiliser will be topdressed. This should be done three times prior to irrigation (or rain) but when foliage is dry. The third application should be completed before the main flush of flowering occurs as utilisation by the crop is poor after this stage.

5.6.13 Systematic “scouting” of the crop after germination is a well-established methodology in other cotton producing areas but an appropriate methodology needs to be employed here. The objective is to record the average number per plant of eggs, small larvae or nymphs of recognisable pests, or evidence of disease. Good scouting also records the incidence of beneficial agents (mainly insects) and evidence of predation and natural biological control. Once an outline methodology has been agreed, begin scouting as soon as possible after germination. Ensure that if a critical threshold is reached for any pest or disease, remedial measures are taken immediately. If possible, this should be an ultra-low volume (ULV) application of a narrow spectrum insecticide or fungicide. Note that pest control after mid-season needs to be justified, as mostly it is neither effective nor economic even though the number of adult pests and damage done are visibly considerable.

5.6.14 Ensure that crops are irrigated on the date projected by scheduling to avoid moisture stress, particularly during the vegetative and boll-swelling phases in cotton, and the flowering phase in other crops. Try to avoid irrigating cotton during the early flush of flowering as excessive water at this stage may cause shedding of the important first flowers and “squares”.

5.6.15 Use a defoliant on cotton if available and do not irrigate after the end of August. Demonstrate the importance of repeated hand harvesting of cotton in order to emphasise the importance of the quality of the first-formed bolls and their contribution to the overall yield. Harvest grain crops before the crop becomes lodged or damaged by birds and before grain has been shed.

6. RECORD SHEETS

6.1 Use WUFMAS forms 23-29 to record important data about the whole farm at the start of the summer season, and form 30 every month. It is necessary to prepare some additional forms in order to record in more detail how the water that is received at the original kolkhoz boundary is being used within it.

6.2 Use WUFMAS forms 31-34 to record all the activities and use of inputs in both the demonstration and control fields. Prepare new forms for recording the pest and disease scouting data.

6.3 Prepare new forms for recording the data collected from monitoring water movement down furrows and across fields.

7. DATABASES

7.1 Enter data from current forms into the WUFMAS databases.

7.2 Create new databases to handle the data from monitoring the farm canals and monitoring in-field water management and pest control.

7.3 Improve validation-on-entry and batch validation of data in the databases in order to reduce the chances of erroneous data being undetected until later stages of analysis.

7.4 Produce regular data summaries for the benefit of participating staff of ministries, institutes, hakimiyats and farms.