Irrig Drainage Syst (2007) 21:251–263
DOI 10.1007/s10795-007-9034-2

Water saving and economic impacts of land leveling: the case study of cotton production in Tajikistan

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Published online: 26 October 2007

Abstract Water conservation is essential to prevent salinity and land degradation in Central Asia. Therefore, field-testing and evaluation of water conservation methods, i.e. laser land leveling in new farming systems of Central Asia is important task. This in mind the International Water Management Institute (IWMI) and its regional partner on IWRM FV (IWRM FV project – Integrated Water Resources Management in Ferghana Valley project is funded by Swiss Development Cooperation (SDC) and conducted jointly with IWMI and Scientific Information Center of Interstate Coordination Water Commission (SIC ICWC) in the Ferghana Valley of Central Asia) project SIC ICWC have conducted 3 year study of impacts of the Laser leveled land leveling on water use, productivity and crop yields in northern Tajikistan. The major research question was laser land leveling an effective water saving tool in the new context of land use and ownership on smaller private plots. Can farmers afford the costs of laser land leveling and how economically viable is it? These research questions were studied in 5 ha laser leveled and neighboring non-leveled (control) fields for 2004–2006. The results showed that laser land leveling can reduce the water application rate in 2004 by 593 M^3/ha, in 2005 by 1509 M^3/ha and in 2006 by 333 M^3/ha in comparison with the unleveled field, located in the similar agro-ecological conditions. The deep percolation was 8% lower and run off 24% less than in non-leveled field. The average annual net income from the laser field was 22% higher than that from the control field. The gross margin from the laser-leveled field were 16. 88 and 171% higher compared to that from the control field for 2004, 2005 and 2006, and on average was 92% higher. In spite of these positive results, there are hindrances on wide application of laser land leveling in Tajikistan. These are absence of initial capital of farmers and scattered land location.

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Keywords Laser leveled land leveling · Water application · Water productivity · Irrigation · Tajikistan

Introduction

The key strategies to cope with water shortages in Central Asia focused on technical water saving methods, such as lining canals, leveling irrigated lands, etc. During the time of the former Soviet Union, water conservation programs such as the Integrated Rehabilitation of Irrigated Areas approach were state funded. They consisted of the following technical activities: (1) consolidation and laser leveling of irrigated fields, (2) lining and equipping of on-farm and intra-farm irrigation and drainage (I&D) infrastructure, (3) rehabilitation of roads along I&D networks, etc. The IRIA program was implemented for large-scale collective farms (*kolkhozes and sovkhozes*), which were part of the state agricultural system.

After the independence, due to the collapse of centralized economic system and increasing budgetary deficit, funding for the water sector substantially decreased in all of the countries of the region. Amongst policy makers and professionals of Central Asia, the prevailing strategy of overcoming the water crisis is still the application of technical water saving methods (Khorst et al. 2001). These technical water saving measures remain at the core of the water management policies of Central Asian countries. However, the effectiveness of the local level technical methods on real water saving for the basin level may be very limited (Droogers and Kite 1999).

Laser leveling of irrigated lands is often advocated as the most effective water saving method in Central Asia. During the Soviet era, millions of hectares of irrigated land were leveled and the technology emerged in the late 1980s as one of the major methods of agricultural improvement. Irrigated farms during the Soviet era were very large and each unit of laser leveling was not less then 100 ha. After the collapse of the Soviet Union, the countries of the region started dismantling collective farms. Instead of hundreds of collective farms (*kolkhozes and sovkhozes*) thousands of private/individual farms with smaller areas were formed. This process is still going on in the region.

In 1980s leveling of surface of the irrigated blocks became major practice in Soviet Central Asian states. The land leveling was applied as water saving method and have shown promising results, water use have been reduced by 1,500 m^3 per ha in leveled fields (Ahmedjanov 1984; Ahmedjanov et al. 1988; Balabanov 1984).

Review of existing literature on land leveling indicated positive impact on water saving, crop and farm productivity (Jonish 1991; Clemmens et al. 1995; Ren et al. 2003; Mallappa and Radder 1993). If it is applied effectively, land leveling increases crop germination and yields and improves water distribution (Rickman 2002).

The land leveling have resulted smoother soil surface, reduction in time and water required to irrigate the field, more uniform distribution of water in the field, more uniform moisture environment for crops, more uniform germination and growth of crops, reduction in seed weight, fertilizer, chemicals and fuel used in cultivation, and improved field trafficability (for subsequent operations). Limitations of laser leveling include high cost of the equipment/laser instrument, the need for a skilled operator to set/adjust laser settings and operate the tractor, and restriction to regularly shaped fields.

During the 2004, 2005 and 2006 crop seasons (April–September), the International Water Management Institute (IWMI) and its regional partner, the Scientific Information Center of Interstate Coordination Water Commission (SIC ICWC), conducted an evaluation of laser leveling under the auspices of the IWRM Fergana project. The study assessed the impacts of laser leveling on crop yields (cotton), water use, water productivity and its economic implications for farm management. This paper presents the results of those activities. The general research hypothesis is that laser land leveling will result in increased crop yields, increased water productivity economic viability and contribute to water conservation in the new context of agricultural development in the region, where a few large collective farms have been replaced by numerous private farms.

Farmers, as entrepreneurs, are unwilling to adopt new technologies unless they clearly see quick and tangible results in terms of farm profitability. Theoretically, a farmer would opt for a new technology if assurance of earning a net profit were shown. Some economists believe that the net returns must be at least 30% higher than for the traditional technology before farmers would consider adoption.

Is laser land leveling an effective water saving tool in the new context of land use and ownership on smaller private plots? Can farmers afford the costs of laser land leveling and how economically viable is it?

Site description and research methods

Site description and land leveling

One of the tasks of the IWRM Ferghana project is to improve water productivity at the field level by pilot testing various water saving methods. Three pilot plots were chosen in Tajikistan to test and demonstrate "best practice" water saving methods for the local farmers. For the laser leveling studies, two adjacent plots were selected; one for land leveling, and another as a "control" field for comparison. Both of the plots are located in the territory of pilot Water Users Association "Zarafshan"[1]. The area of the study is typical and has a very arid climate, with 120–160 mm/year of precipitation, mainly occurring during winter (December–February) and spring (March–April) seasons. The air temperatures in summer average 22–28°C and may reach as high as 40°C. The winter average temperatures are 6 to 8°C, sometimes dropping to as low as −15°C.

Laser leveling of the pilot 5 ha site was done using a K-700 heavy (600 HP) Russian made tractor with leveling equipment. It was done in late March, 2004. The field was not topsoiled (top soil of the field was not removed and later replaced). After the laser, leveling was completed, the farmer insisted on working both fields to 40–60 cm depth with a ripper plough. The perception of the farmer was that, by ploughing the field, it would be possible to break the plough pan, formed at 30–40 cm both fields due to long cotton monoculture.

An independent expert, who conducted a topographic survey after completion of the laser leveling, assessed the quality of the laser leveling. The survey has indicated 4% difference between projected and actual cut and fill heights that are well within the permitted limits for land leveling. However, the basic design was flawed with a gradient down and across the field instead of just down the field.

Soil characteristics

Immediately after the selection of the pilot (laser leveling) and control fields, soil surveys were conducted to determine the soil properties. The chemical and physical attributes of the pilot and control fields were determined for 0–30 and 30–70 cm soil depths. The soils of both fields are not saline, having maximum EC equal to 0.2 dS/m with a standard deviation of 0.05. The EC of the lower soil layer (30–70 cm) is 50% higher means than in the top soil

[1] IWRM Ferghana project has one pilot canal, one pilot Water Users Association in territory of Fergana Valley section Kyrgyzstan, Uzbekistan and Tajikistan.

layer (0–30 cm) at both sites. The soil bulk density is moderate at a maximum of 1.38 g/cm^3 and a minimum 1.32 g/cm^3. The bulk densities of the laser-leveled field were lighter than those of the control field (Table 1). The content of the organic matter in the soils of the control and laser fields had maximum value of 0.84%, which is very low for the loamy soils of the Central Asia. The normal content of the organic matter for such soils is 1.2–1.5% (Kovda 1982). The 0–30 cm soil layer of the control field had higher levels of extractable N, P and K then the laser-leveled field. Both laser and control fields have significant amounts of clay, with a maximum of 38.2% for the 30–70 cm depth of laser field and minimum of 33.6%. The chemical and physical properties of the soils of laser and control fields are representative of the irrigated soils of the Fergana Valley (Mukhamedjanov et al. 2004).

Research and monitoring methods

The following data were collected (1) direct measurements of the water applied and the runoff from the field, (2) crop development stages, records of the inputs and costs of agricultural operations, (3) ETo (crop reference evapotranspiration, precipitation).

During the crop season, two trained field staff monitored agrotechnical operations and collected information on each item every 10 days period. The inlets and the outlets of the laser and control fields were equipped with weirs and water related information was recorded in field journals for each irrigation, conducted in every crop season.

Crop development was monitored every 15 days by a field technician and an observer. In both fields, five plots of 2×2 m^2 were selected for monitoring and recording of the crop growth and were located in a diagonal line across the field. The crop information included cultivar, sowing and, germination dates, crop height, cotton boll formation date, boll numbers and yield. This paper presents cotton yields in terms of seed yield not as lint.

The impact of laser land leveling on water application was assessed through calculation of the water balance for laser and control fields.

$$\sum \Delta W = \mathrm{Ir} + P - \mathrm{ET} - \mathrm{Rn} - \mathrm{DP}, \quad \mathrm{M}^3/\mathrm{ha} \tag{1}$$

Where:

P precipitation
ET crop evopotranspiration

Table 1 Selected soil chemical and physical properties of the Control and Laser leveled plots

Fields	Soil layer, cm	Conductance EC 1:1, dS/m	Volumetric weight, g/cm^3	Content humus, %	Content potassium–K, mg/kg	Content phosphorous–P, mg/kg	Content nitrates – N-NH_4, mg/kg	Content clay, %
Control field	0–30	0.1	1.37	0.84	245	21.51	23.6	35.1
	30–70	0.2	1.38	0.67	163	15.6	16.9	36.9
Laser leveled field	0–30	0.1	1.36	0.82	189	18.5	16.7	33.6
	30–70	0.2	1.32	0.73	194	15.7	16.9	38.2
Standard deviation		0.05	0.02	0.08	34.3	2.7	3.4	2.02
Maximum		0.2	1.38	0.84	245	21.5	23.6	38.2
Minimum		0.1	1.32	0.67	163	15.6	16.7	33.6

I–O Surface inflow and outflow
Ir irrigation water supply
Ig–Og inflow and outflow of ground water
Rn run off from field
Dr drainage
DP deep percolation
Lc seepage from canals

If the groundwater table below the field is table is $\sum \Delta W=0$, therefore Eq. 1 can be written

$$\text{Ir} + \text{P} = \text{ET} + \text{Rn} + \text{DP}, \quad \text{M}^3/\text{ha} \tag{2}$$

The major component of the water balance – evopotranspiration, precipitation were measured daily for whole period of studies. An evopometer «Atmometers» (ET gage®) and precipitation gauge were installed for both fields. The evopotranspiration from irrigated field then calculated using following equation:

$$\text{ET} = Kc \times \text{ETo}, \quad \text{M}^3/\text{ha} \tag{3}$$

ET potential crop evapotranspiration
Kc crop coefficient (for cotton in Tajikistan from 0.5 up to 1.5 – Mukhamedjanov et al. 2004)
ETo reference crop evopotranspiration (seasonal average, calculated using daily measured means)

In Eq. 2 DP – deep percolation is unknown and not measured therefore the water balance equation was changed to:

$$\text{DP} = \text{Ir} + \text{P} - \text{ET} - \text{Rn}, \quad \text{M}^3/\text{ha} \tag{4}$$

Water productivity and economic analysis

Water productivity analysis combines physical accounting of water with yield or economic output to assess how much value is being obtained from the use of water (Molden et al. 2003). For this analysis, physical water productivity was calculated by:

$$\text{WP} = \text{Output}/Q \tag{5}$$

where: WP is the productivity of water in kg/m^3, Output is the mass of crop in kilograms and Q is water resources applied and depleted (m^3). In this study, only physical productivities of the applied and depleted water are analyzed.

To compare the laser-leveled field to the control field, both gross margin analysis and partial enterprise budgeting techniques[2] were applied for three cropping seasons of 2004, 2005 and 2006.

[2] The use of partial enterprise budgets required to evaluate technological innovations compared to old techniques, as the capital costs associated must be discounted over the live of the new investment. Some examples of application are provided by Kormawa et al. (1999), and Alimi and Ayanwale (2004).

Irrigation dose, timing and duration

In 2004, the irrigation of the both fields was scheduled based on soil moisture changes in the 1-m soil depth. Whenever the soil moisture content in 1-m soil depth decreased below the 30% (70% of field capacity), irrigation water was applied. The value of field capacity for the laser field equal to 21–22%, or 0.6 pF in terms of soil moisture suction and for the control field FC was 14–20% or 0.5 pF in terms of soil moisture suction.

In 2005, the farmer/owner was given the irrigation schedule developed for 2004 with the choice to either irrigate on this schedule or continue his own earlier practices. This was done in order to check the influence of the irrigation practices of the farmer on the water impacts of the laser leveling.

The field personnel collected soil samples for moisture determination from five depths (0–0.05, 0.05–0.2, 0.2–0.4, 0.4–0.6 and up to 1 m) every 3 days. The soil moisture was determined gravimetrically. The soil samples were measured and dried at the field station. The gravimetric weights of the soils samples were measured immediately after sampling then dried for 24 h at 105°C and weighed again.

In all 3 years, furrow irrigation was used on the laser field and control fields. This is the main irrigation method in most of parts of the Fergana Valley and in Central Asia in whole. Water was applied based on soil moisture dynamics in 2004 and farmer's irrigation experience in 2005, 2006 seasons.

The following research hypotheses were tested in this study: (1) laser leveling will increase cotton yields at least by 30% of pre-land leveling period, (2) land leveling will improve uniformity of water distribution in the field and will save 30–35% of water from deep percolation at the field and 20% for faming system, (3) the leveled field will require at least 50% less labour and irrigation time and (4) laser land leveling is economically viable for new emerging farmers in Tajikistan.

Results and discussions

Impacts of laser leveling on crop yields

The control and laser leveled fields were managed by one farmer who had been assigned to grow cotton for the previous 3 years. The yields of cotton in 2003 (pre-land leveling period) were 2.1 ton/ha for the test field and 2.3 ton/ha for the control field. The Fergana-3 variety was sown at the same time in both fields in 2004, 2005 and 2006. The average yields of cotton in the control and the laser fields were determined over three replications for each harvest pass and in each year, both fields were harvested four times. The highest total yield of 3.98 ton/ha was observed in the laser leveled field in 2005 and the highest control yield was 2.52 ton/ha in 2004 (Table 2). Crop yields increased in the laser leveled field from 2.71 ton/ha in 2004 to 3.98 ton/ha in 2005 i.e. by 47% and to 3.38 ton/ha in year 2006 (24.7%). By contrast, cotton yields in the control fields remained constraint at 2.52 ton/ha in 2004 to 2.50 ton/ha in 2005 and 2.47 ton/ha in 2006.

The yield difference between laser leveled and "control" fields was 8% in 2004, increased to 59% in 2005 and 27% in 2006. In all 3 years, the laser field had consistently higher crop yields.

If take into account that both fields located in the same area and sequence of agronomic operations and the amounts of inputs in both fields were similar then the higher cotton yields in 3 years can be attributed to better water management: uniform water distribution in

Table 2 Cotton yields in laser leveled and control fields for years 2004 and 2005, in tons/ha

Fields	Replications and statistics	Year 2004	Year 2005	Year 2006
Laser leveled field	1st rep	2.7	3.98	3.48
	2nd rep	2.8	3.9	3.56
	3rd rep	2.64	4.05	3.38
	St. Dv	0.081	0.075	0.0057
	Average	2.71	3.98	3.47
Control field	1st rep	2.51	2.48	2.57
	2nd rep	2.61	2.59	2.48
	3rd rep	2.44	2.44	2.37
	St. Dv	0.085	0.078	0.101
	Average	2.52	2.50	2.47

the field, reduced deep percolation and drainage from the laser leveled field. The detailed description of water impacts of the laser leveling is presented in the next sections.

Impacts of laser leveling on water use and productivity

Water balance analysis

For the analysis of the impact of the laser land leveling on water use components of the water balance was calculated for each field for all years of study (Table 3). The first component is the water supply (Ir) to the irrigation fields. In 2004, total water supply to the laser field was 6,570 and 7,163 M^3/ha for the control field.

In 2005 (irrigation decided by farmer) the laser and control fields received 7,923 and 9,432 M^3/ha water, respectively. In 2006 the laser field received 6,997 M^3/ha and control field 7,330 M^3/ha. The water supply increased by 21% in 2005 in comparison with 2004 and then declined by 12% in 2006 in comparison of 2005 in the laser field. In the control field in 2005 water supply increased by 23% in comparison with 2004 and declined by 22% in 2006 in comparison with 2005. Laser leveled field was supplied with less water under the farmer managed irrigation. In 2005 and 2006, the difference on water supply between the two plots were 14–16%, lower for the laser treatment.

The precipitation was the same for both fields, being rate of 63 mm in 2004, 82 mm in 2005 and 53 mm in 2006.

Ran off (Rn) from the fields was measured for each irrigation and sum for the season was used for water balance. In 2004, total of 1,219 m^3/ha discharge from the laser leveled field, amounting 19% of the water supply compared to 1,710 M^3/ha or 22% of water supply

Table 3 Water balance for laser leveled and control fields for 2004–2006, in m^3/ha

Years	Fields	Water supply – Irrigation Ir	Precipitation, *P*	ET Potential Evopotranspiration	Rn Run off	DP Deep percolation
2004	Laser leveled field	6,570	630	3,600	1,219	2,381
	Control field	7,163	630	3,680	1,710	2,403
2005	Laser leveled field	7,923	820	4,200	2,641	1,902
	Control field	9,432	820	4,350	3,579	2,323
2006	Laser leveled field	6,997	530	3,750	939	2,838
	Control field	7,330	530	3,860	1,022	2,978

in the control field. In 2005, the runoff from the laser field was 2,641 M^3/ha, rate or 33% of the water supply and in 2006 run off was equal to 939 M^3/ha or 13%, which is the lowest, run off rate. The rate of discharge from the control field in 2005 was 3,579 m^3/ha or 38% of the water supply and 1,022 M^3/ha or 14% of water supply was in 2006. The field drainage was high for both fields, even under controlled conditions in 2004, equal to more than 20% of the water supply. This increased in 2005, reaching more than 30% of the water supply. The high discharge is due to the water re-use practice widely applied in this areas. The fields located lower in the terrace re-use the discharge from the upstream fields. In practice, upper fields usually pass water to the lower areas, resulting in land erosion on many fields in the study area. No dramatic decline in run off was observed in 2004 and 2005, because the farmer generally continued with this practice. However, in 2006 the run off from both field declined. This may because 2006 was a water scarce year in Central Asia (Dukhovniy and Sokolov 2005).

The deep percolation (DP) for the laser leveled and control field was calculated using Eq. 4 resulted from water balance Eqs. 1, 2, and 3. The deep percolation in 2005 for laser leveled field was 2,381 and 2,403 M^3/ha for control field. The difference of DP between the two fields was minimal (only 22 M^3/ha). In 2005 DP for laser leveled field was 1,902 and 2,323 M^3/ha for control field. The laser leveled field had 421 M^3/ha less DP. In 2006, the DP rates for laser leveled field was 2,838 and 2,978 M^3/ha for control field, the difference is 140 M^3/ha less DP for laser leveled field.

For the period of study (2004–2006), the irrigation regime and methods in both fields were similar. However, the water application, run off and deep percolation in laser leveled filed were lower in comparison in control field, but the same time it had higher crop yields.

Water productivity analysis

The analysis of the impacts of laser land leveling on water productivity was based on the comparison of the water application productivities of laser and control fields for the period of monitoring (2004–2006). The water productivities were calculated using Eq. 5. In water productivity calculations as an output was used average cotton yields for each field (Table 2) and applied water were used as Q from water balance calculations (Table 3).

The applied water productivities (WPa) for the laser field had increased from 0.41 kg/m^3 in 2004 to 0.50 kg/m^3 in 2005 and 2006 or by 22%. The productivities of supplied water in the control field have declined from 0.35 kg/m^3 in 2004 to 0.27 kg/m^3 in 2005, the rate of decline is 23%. However, in 2006 WPs in control field increased to 0.34 kg/m^3. The WPs of laser were 15% higher in 2004, 46% in 2005 and 32% in 2006 (Table 4).

The laser-leveled field had consistently high productivities in all years of study (2004–2006).

Table 4 Physical water productivities in laser leveled and control fields in 2004–2006, kg/m^3

Years	Laser field	Control field	Difference between water productivity	
			kg/m^3	Percent
2004	0.41	0.35	0.06	15
2005	0.50	0.27	0.23	46
2006	0.50	0.34	0.16	32

Impact of laser leveling on operation time and labour efficiency

Experience elsewhere indicates that land leveling should reduce the time of watering and the labour need per ha (Khorst et al. 2001; Rickman 2002). The details of operation time and labour use for laser and control fields are given in Fig. 1.

The labour input to irrigate the laser leveled field in 2004 was 42 person-hours, in 2005 34 person-hours and in 2006 40 h. The same indicator for the control field was 65 h in 2004, 34 h in 2005 and 66 h in 2006. Laser leveling result 23 h less labour in 2004, 0 h in 2005 and 26 h in 2006.

Analysis of impacts of laser leveled leveling – crop–water–labour

The cotton yields in laser-leveled field for period of study has increased by 26%, water productivity of applied water by 32%. The deep percolation in the same field reduced 8%, run off by 24% and irrigation time reduced by 6%, labour input by 29% (Table 5).

The above analysis indicates that laser land leveling a good technology for future use. This, however, is constrained by its cost. The following section of paper presents economic analysis of laser leveling study.

Economic analysis of laser leveling

For comparing the economic performance of the laser leveling to conventional leveling, net incomes, and gross margins (Ahmad et al. 2001) were worked out (Table 6) for the cropping seasons of 2004, 2005 and 2006, and a partial budget (Dalsted and Gutierrez 2004) for 5 ha enterprise was prepared based on the average performance during the 3 years (Table 7). The partial budget was particularly helpful as the farmer decided to apply different dozes of fertilizers and pesticides to the laser plot compared to the control plot. In addition, the farmer had to partially rip the soil in the laser field after the leveling operation, as the top soil from some parts of the field was moved to other areas of the field, and the farmer feared a decline in fertility. Such a fear was justified in view of the earlier findings, such as those by Walker et al. (2003), who indicates that yields can be reduced during the first year after precision land leveling in many soil types, but the reduction may or may not

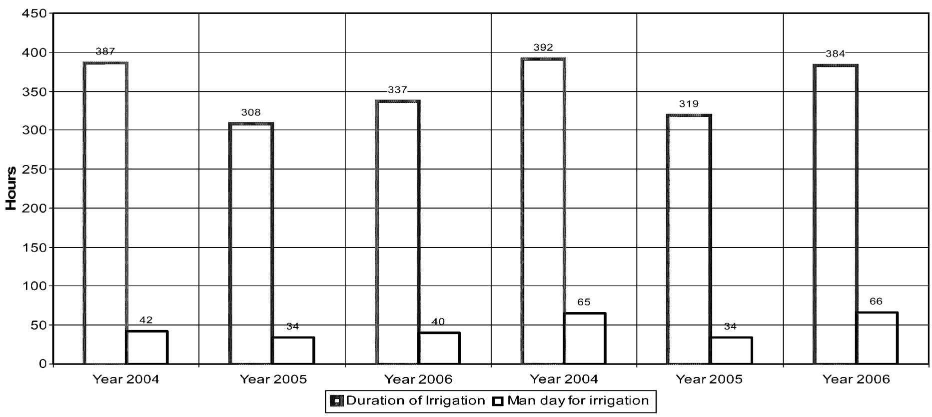

Fig. 1 Comparison of operation time and labour efficiency

Table 5 Resulted impact of laser leveling (average for 2004–2006)

	Cotton yields, t/ha	DP Deep percolation	Run off	Water productivity WPa kg/m^3	Duration of irrigation, hours	Labour input for irrigation hours
Laser leveled field	3.39	2,374	1,600	0.47	344	39
Control	2.50	2568	2,104	0.32	365	55
Difference	0.89	194	504	0.15	21	16
	26%	8%	24%	32%	6%	29%

be nutrient related. The ripping was useful in loosening the compact soil. Partial budget can evaluate changes in both fixed and variable resource use (Dalsted and Gutierrez 2004).

The net income analysis shows that compared to the control field, there were some cost savings in the laser field related to tillage, labor, and irrigation water, while there were additional costs due to laser leveling and ripping, pesticides, transportation and taxes on additional output. Interestingly, even though the water application was reduced for the laser field, it did not have much impact on total costs as water is priced quite cheaply (6 somani/1,000 m^3 or US$ 2/1,000 m^3). Though the net income from the laser leveled field was negative during the first year, it was 41 and 28% higher compared to that of control field in 2005 and 2006. The average annual net income from the laser field was 22% higher than that from the control field. The gross margin from the laser field was 16, 88 and 171% higher compared to that from the control field for 2004, 2005 and 2006, and on average was 92% higher.

Table 6 Net income and gross margin analysis of laser leveling (Costs in Tajik Somani/ha)

Description	Control field				Laser field			
	2004	2005	2006	Average	2004	2005	2006	Average
Fixed costs								
Discounted annual laser leveling cost	0	0	0	0	499	499	499	499
Discounted annual ripping cost	0	0	0	0	40	40	40	40
Fixed social security contribution	211	279	221	237	211	279	221	237
Total average fixed costs (FC)	211	279	221	237	750	818	760	776
Variable costs				0				0
Tillage and cultivation expenses	346	258	454	353	346	332	233	304
Seed costs	48	48	48	48	48	48	48	48
Labor costs	626	559	745	643	535	501	859	632
Pesticides costs	0	0	95	32	99	82	95	92
Fertilizer and manuring costs	395	247	315	319	451	545	409	468
Cost of irrigation water	46	41	44	44	39	35	42	39
Transportation costs	24	11	36	24	23	28	40	30
Variable taxes on yield	102	65	50	72	116	130	69	105
Total variable costs (TVC)	1,587	1,229	1,787	1,534	1,657	1,701	1,795	1,718
Total costs (TC=fixed plus variable)	1,798	1,508	2,008	1,771	2,407	2,519	2,555	2,494
Total gross value of production (GVP)	2,153	2,137	2,384	2,225	2,316	3,407	3,414	3,046
Net farm income (GVP-TC)	355	629	376	453	−91	888	859	552
Gross margin (GVP-TVC)	566	908	597	690	659	1,706	1,619	1,328
Net farm income of laser field as % of control				0	(26)	141	228	122
Gross margin of laser field as % of control				0	116	188	271	192

Table 7 Partial enterprise budget summary for 5 ha plot for 5 years based on 2004/2006 average performance (in Tajik Somani at 2004 prices)

Costs		Returns	
Additional costs		Additional returns	
a. Laser leveling and ripping	13,475	a. Value of additional outputice	20,525
b. Additional fertilizers	3,725		
c. Additional transportation	150		
d. Additional variable taxes	825		
Total additional costs	18,175		
Reduced returns	0	Reduced costs	
		a. Cultivation expenses	1,225
		b. Labor costs	275
		c. Cost of irrigation water	50
		Total reduced costs	1,550
A. Total additional costs and reduced returns	18,175	B. Total additional returns and reduced costs	22,075
Net change in income due to laser leveling (B−A)	3,900		

The partial enterprise budget (Table 7) indicates that the additional benefits coupled with costs savings for labor, cultivation and irrigation outweighed the additional costs, and the projection for net economic gain due to laser leveling during the life of leveling[3] will remain positive, and on average the farmer will have an additional income of 1,300 US$ from the 5 ha plot due to laser leveling, or 260 US$/ha or 52 US$/ha/year. Thus, from an economic point of view, laser leveling does appear to be an attractive option.

Discussions and conclusions

The cotton yields in the laser-leveled field in 2004 had been 7.5%, in 2005 were 59% higher and in 2006 were 26% higher than in the neighboring control field under similar agro-environmental condition, agricultural operations and inputs.

Laser leveling had resulted increased crop yields, improved water use and water productivity. The water application in laser leveled field reduced in 2004 by 593 M^3/ha, in 2005 by 1,509 M^3/ha and in 2006 by 333 M^3/ha in comparison with the non-leveled field, located in the similar agro-ecological conditions. In the laser field, the deep percolation was 8% lower and run off 24% than in non-leveled field. The water productivity in laser leveled field increased by 32% in comparison with non-leveled field of the same sizes. The irrigation time reduced by 6% and labour input for irrigation by 29%.

The net income was negative at the laser field during the first year, which has been reported elsewhere too (Walker et al. 2003), but it was 41 and 28% higher compared to that of control field in 2005 and 2006, respectively. The average annual net income from the laser field was 22% higher than that from the control field. The gross margin from the laser field was 16, 88 and 171% higher compared to that from the control field for 2004, 2005 and 2006, and on average was 92% higher. The increasing trend in the gross margin reflects that compared to the control field, the yield might be higher in the several future years too.

[3] It is assumed that the field will need another laser leveling, though not as rigorous as that of 2004 after 5years.

The results of the partial enterprise budget indicate that the additional benefits coupled with costs savings for labor, cultivation and irrigation outweighed the additional costs, and the projection for net economic gain due to laser leveling during 5 years projected life of leveling will be positive. On average, the farmer will have an additional income of 1,300 US$ from the 5 ha plot due to laser leveling in, or 52 US$/ha/year. Thus, from an economic point of view, laser leveling does appear to be an attractive option.

As the laser land leveling has shown promising results in a topographically difficult terrain of Tajikistan, where the soils have high gravel content, low organic matter, and issues related to slope, the agricultural extensions agencies should promote this technology in the irrigated areas of Tajikistan. The government might have to facilitate soft loans and other credit facilities for the cash short farmers of Tajikistan to help application of the technology at a wider scale. The Farmer Ownership Model Project (IFC, undated) might serve as a good model for outscaling the precision land leveling under Tajik Conditions.

Acknowledgements Authors are grateful to the support of SIC researchers, especially Dr. Mukhamedjanov S.Sh, Dr. Nerozin S.A and Dr. Galustian A, for support of carrying out the research. The authors want to also acknowledge the assistance of Mr. Yuldashev Tulkun for support on data analysis, Mr.Karimov Salim and Mr. Khusenov Zie for the support during the data collection and field monitoring. We are also grateful for the financial support of the Swiss Development Cooperation (SDC).

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