Technical Efficiency of Using Water and Soil Resources in Samarkand

-A Case Study of Samarkand region, in Uzbekistan-

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INTRODUCTION

- **The scale of producing agricultural products has increased:**

- in 2013 the trend for the industry rose by 2.4 times more than the trend in 2000;
- the share of agriculture in 2000 was 30.1 %, while in 2013 this trend reached 16.8 % (*SCRUz, 2013*).

- **The amount of water used for agriculture** (*MAWR, 2015*):

- in 1985 year is 22.4 thousand m^3
- 2010 diminished until 12.2 thousand m^3

- **Situation on crops fields between 1991 and present:**

- wheat fields increase from 25.7 % to 45 %;
- vegetables, potatoes and other crops fields increase from7 % to 8.8 %;
- cotton field decrease from 41.9 % to 35.4 %.

Challenges:

1. Soil fertility:

- 49 % of irrigated lands experienced high change of salinity (*Nurmatov & Kamilov, 2013*);
- the lowest category of the soil quality - more than 23 % (*Ramazonov & Yusupbekov, 2003*)

2. Domestic water resources :

- the demand has been meeting by 40.0 % with domestic water resources

Research Objective

- to examine technical efficiency of production for cotton and wheat in Samarkand region by Mathematical model (Data Envelopment Analysis) and Econometric estimation production function (Cobb-Douglas)

MATERIALS AND METHODS

MATERIALS

The number of survey questions in location of the Samarkand region in Uzbekistan

#	Districts:	Farmers
1**	Bulungur	4
3*	Ishtikhon	7
4*	Kattakurgan	9
5*	Narpay	1
8*	Payariq	13
9*	Pasdargom	7
12**	Toyloq	2
13**	Urgut	4
	Total:	**47**

#	Production	Farmers
1*	Cotton and wheat	37
2**	Wheat and vegetables	10
	Total:	**47**

METHODS

- **Mathematical model (Data Envelopment Analysis, CRS – DEAP 2.1)**
  (Coelli, 1996); (William W. Cooper, Lawrence M. Seiford, Joe Zhu, 2011)

Max u,v $(u'y_i/v'x_i)$,	Max μ,ν $(\mu' y_i)$,	Min θ,λ θ,
St $u'y_i/v'x_i \leq 1$,	st $\nu' x_i = 1$,	St $-y_i + Y\lambda \geq 0$,
j=1,2,3…,N,	$\mu' y_j - \nu' x_j \leq 0$, j=1,2,3…,N,	$\theta x_i - X\lambda \geq 0$,
$u,v \geq 0$	$\mu, \nu \geq 0$,	$\lambda \geq 0$,

i – farmer, x_i – resource usage, y_i – product production, u′- manufactured products (vector), v′ - resource (vector), μ - the notation change from u and v to μ and ν reflects the transformation, θ – scalar, λ – vector of constants,

- **Econometric estimation production function (Cobb-Douglas)**

$$\mathbf{Ln\ Y_{yield} = I_{intercept} + \alpha\ Ln\ W_{water} + \beta\ Ln\ O_{organic} + \lambda\ Ln\ Ch_{chemical} + \mu\ Ln\ F_{fuel} + \nu\ Ln\ L_{labor} + E_{error}}$$

Where Y is the total quantity of crops cultivated (in kilogram);
W-amount of water employed (in m^3);
Or_fert (O) – amount of organic fertilizer employed (in kilogram);
N_Ch_fert (N) – amount of Nitrogen Chemical fertilizer employed (in kilogram);
F – amount of fuel employed (in kilogram);
L – amount of workers employed
E – standard eror
α, β, λ, μ and ν are the output elasticity of labor, organic fertilizer, chemical fertilizer, fuel and labor, respectively

Technical efficiency of producing cotton*

Farmers	Yield, kg	Land, ha	Water, m^3/ha	Or_fert., kg/ha	N_fert., kg/ha	Fuel, kg/ha	Labor, hour/ha	TE
Mean	76261	28	221370	60484	17363	6495	40328	0.95
Max	173568	64	460936	141120	39872	15552	92864	1.00
Min	30610	10	91330	18768	6630	2090	17960	0.83

TE	Farmers, %
=1	22.0
≥0.96, ≤0.99	32.0
≥0.91, ≤0.95	35.0
≤0.90	11.0

If the use of resources of 37 farmers are diminished to 5.0 % it will be possible to obtain the intended gross product or achieve other favorable results.

* Or_fert. - Organic fertilizers, N_fert. - Nitrogen fertilizers, TE - technical efficiency

Predicted values give technical efficiency equal to one producing cotton*

#	Land	Predicted values (per ha)						Land	Real data/Predicted values				
		Y	W	O_f	N_f	F	L		W	O_f	N_f	F	L
Mean	25	3061	7662	2282	638	229	1541	0.91	1.06	0.97	0.98	1.02	0.96
Max	61	4373	10495	4176	804	288	2125	1	1.47	1.17	1.12	1.24	1.02
Min	7	2346	6304	1104	533	204	1122	0.7	0.84	0.84	0.78	0.73	0.78
1	**Shortages of resources, (< 1)**								19.0	48.0	46.0	27.0	54.0
2	**Excessive use of resources, (> 1)**								49.0	22.0	30.0	49.0	16.0
3	**Normal use of resources, (= 1)**								32.0	30.0	24.0	24.0	30.0
	Farmers, %								100	100	100	100	100

*Y – yield, W-water, O_f. - organic fertilizers, N_f. - nitrogen fertilizers, F-fuel, L-labor

Technical efficiency of producing wheat*

Farmers	Yield, kg	Land, ha	Water, m^3/ha	Or_fert., kg/ha	N_fert., kg/ha	Fuel, kg/ha	Labor, hour/ha	TE
Mean	84686	22	119434	24609	10328	2330	3013	0.89
Max	205972	56	325658	51185	28947	5667	7905	1.00
Min	23483	5	28523	8796	2153	538	727	0.70

TE	Farmers, %
=1	21.0
≥0.96, ≤0.99	13.0
≥0.95, ≤0.91	17.0
≤0.90	49.0

Even though farmers (of 47) are expected to utilize resources less by 11.0 %, they are likely to achieve the intended or more than the intended results.

* Or_fert. - Organic fertilizers, N_fert. - Nitrogen fertilizers, TE - technical efficiency

Predicted values give technical efficiency equal to one producing wheat*

#	Land	Predicted values (per ha)						Land	Real data/ Predicted values				
		Y	W	O_f	N_f	F	L		W	O_f	N_f	F	L
Mean	18	5630	1373	497	110	137	5630	0.83	0.97	0.92	0.95	0.97	1.00
Max	46	7178	3767	557	116	151	7178	1	1.2	1	1.09	1.05	1.14
Min	5	4007	586	431	101	117	4007	0.54	0.72	0.72	0.72	0.87	0.92
1	**Shortages of resources, (< 1)**								46	66	60	55	28
2	**Excessive use of resources, (> 1)**								26	0	17	13	36
3	**Normal use of resources, (= 1)**								28	34	23	32	36
	Farmers, %								100	100	100	100	100

*Y – yield, W-water, O_f. - organic fertilizers, N_f. - nitrogen fertilizers, F-fuel, L-labor

Table 1: The analysis of cotton production function

Variables	Coefficients	Standard Error	t-Stat
Y-intercept	0.803	0.872	0.921
Ln_Water	-0.091	0.094	-0.970
Ln_Or_fert	0.134	0.049	2.745
Ln_N_Ch_fert	0.287	0.109	2.621
Ln_Fuel	0.174	0.138	1.262
Ln_Labor	0.564	0.103	5.470
Number of observations	37		
Adjusted R^2	0.869		

Table 2: The analysis of wheat production function

Variables	Coefficients	Standard Error	t-Stat
Y-Intercept	0.521	2.528	0.206
Ln_Water	0.107	0.111	0.958
Ln_Or_fert	0.292	0.039	7.389
Ln_N_Ch_fert	0.785	0.172	4.551
Ln_Fuel	0.138	0.430	0.319
Ln_Labor	-0.141	0.311	-0.452
Number of observations	47		
Adjusted R^2	0.669		

CONCLUSIONS AND SUGGESTIONS

❑ Conclusions

- irrigation water has not been utilized efficiently at a farmer level;
- farmers try to take advantage of a chance water comes to their fields even though water irrigated is excessive than required;
- more resources are employed for irrigating cotton lands in comparison with the amount of water used for cultivating wheat crops;
- organic and mineral fertilizers are significant in cotton and wheat production;
- labor is more significant for cotton cultivation than wheat;

❑ Suggestions

According to the analysis of the study if the use of mineral fertilizers on cotton and wheat lands is increased it influences positively on the production efficiency. There is **no doubt that mineral fertilzers increase** the production efficiency. However, it has the same level of adverse effects on **the sustainable use of crop lands**. In other words, it s consequent effect might **be the erosion** which develops over the years. Therefore the following measures might be useful in order to provide sustainable usage of water and soil resources in the future:

- ❑ Reducing the scope of cotton-wheat lands in order to achieve high level of efficiency from the cotton and wheat lands and high level of efficiency in using water and soil resources.
- ❑ Implementing the system of effeicient and fast delivery of information about irrigation due dates of the farming lands among the farmers;
- ❑ Working out the opportunities for the wide and multi use of organic fertilizers;
- ❑ Implementing the system of cultivating fruit-vegetables, lemunious crops and many years crops on the previously cotton and wheat lands in order to enhance the fertility of the lands and soil;

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William W. Cooper, Lawrence M.Seiford, Joe Zhu. 2011, Data Envelopment Analysis: History, Models, and Interpretations. Handbook on Data Envelopment Analysis, 2nd ed. USA: Springer; 1-39, 497(2).

MAWR- The Ministry of Agriculture and Water resources of Uzbekistan, www.agro.uz

www.samarkand.uz/about_region/general_information - Official Web site of Samarkand regional.

Thank you for your attention!

ご清聴ありがとうございました！

E'tiborlaringiz uchun rahmat!

Households(dehkan)

livestock farmers

poultry

sheep breeding

organic fertilizers

before plowing

fertigation

after *crop rotation:*

cotton ✖ *wheat* ✔

Not modern package like Japan

Usage: independent by farmers

Usage: supply by Government

types of **mineral fertilizers**: *nitrogen, phosphorus* and *potassium*

The Future Plan

- to estimate by using the *Stochastic Frontier Production Functions (SFPF) method* of **Economic** (*Technical and Allocative*) **Efficiency** of using water and soil resources by using existing biological, empirical and economical data of farmers (cotton and wheat; wheat and vegetables, fruits, grapes) in Samarkand region;

- to analysis of socio-economic improvement of use water and soil resources in farmers;

- working out and assessing optimal scenarios on improvement of agricultural production.

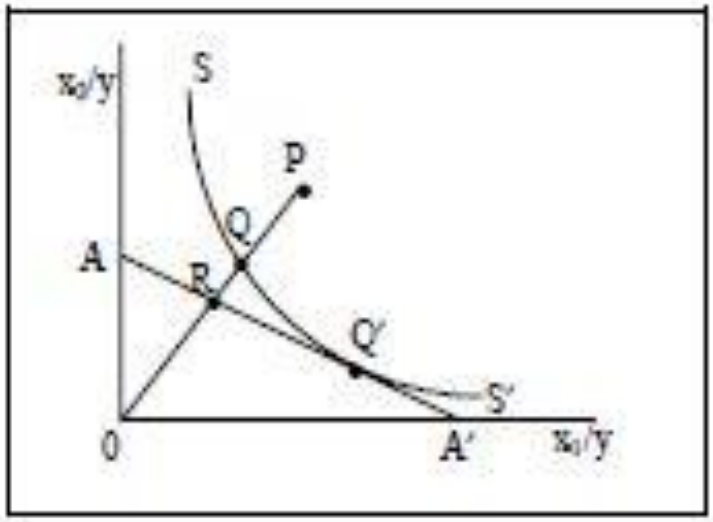
Data envelopment analysis (DEA) model

-Efficiency in production is achiev when a farmers' output is produced in the best and most profitable manner(Johansson, 2005). Efficiency measurement begins with Farrell (1957) who drew upon the work of Debreu (1951) and Koopmans (1951) to define a simple measure of firm efficiency which could account for multiple inputs. Efficiency consists of two components:

*- **Technical efficiency**, which gives the capacity of a farm to achieve the highest output with the given level of inputs;*

*-**Allocative efficiency**, which reveals the capacity of a firm to apply the inputs in optimal quantities at given prices.*

These two measures are then combined to provide a measure of total economic efficiency(Coelli, 1996).



Technical and Allocative Efficiencies

$TE_I = OQ / OP$

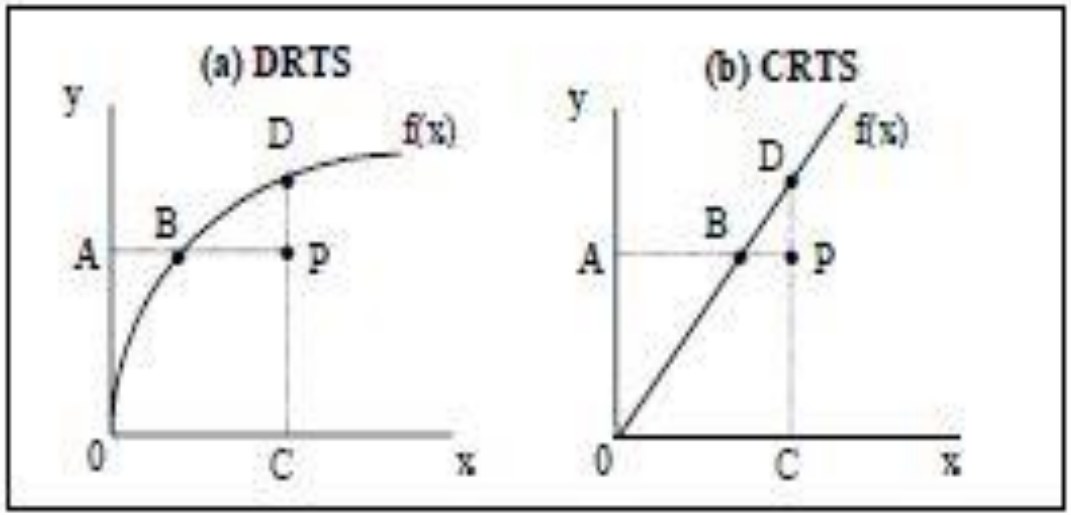
$AE_I = OR / OQ$

$EE_I = TE_I \times AE_I = OR / OP$

$TE_{IOM} = AB / AP$

$TE_{OOM} = CP / CD$

The constant returns to scale(figure b) - AB / AP = CP / CD



Input – and Output – Orientated Technical Efficiency Measures and Returns to Scale

- **Total agriculture land** in Samarkand region: 1295.0 thousand hectares (77% of total land)
- **Total irrigated land**: 24 %

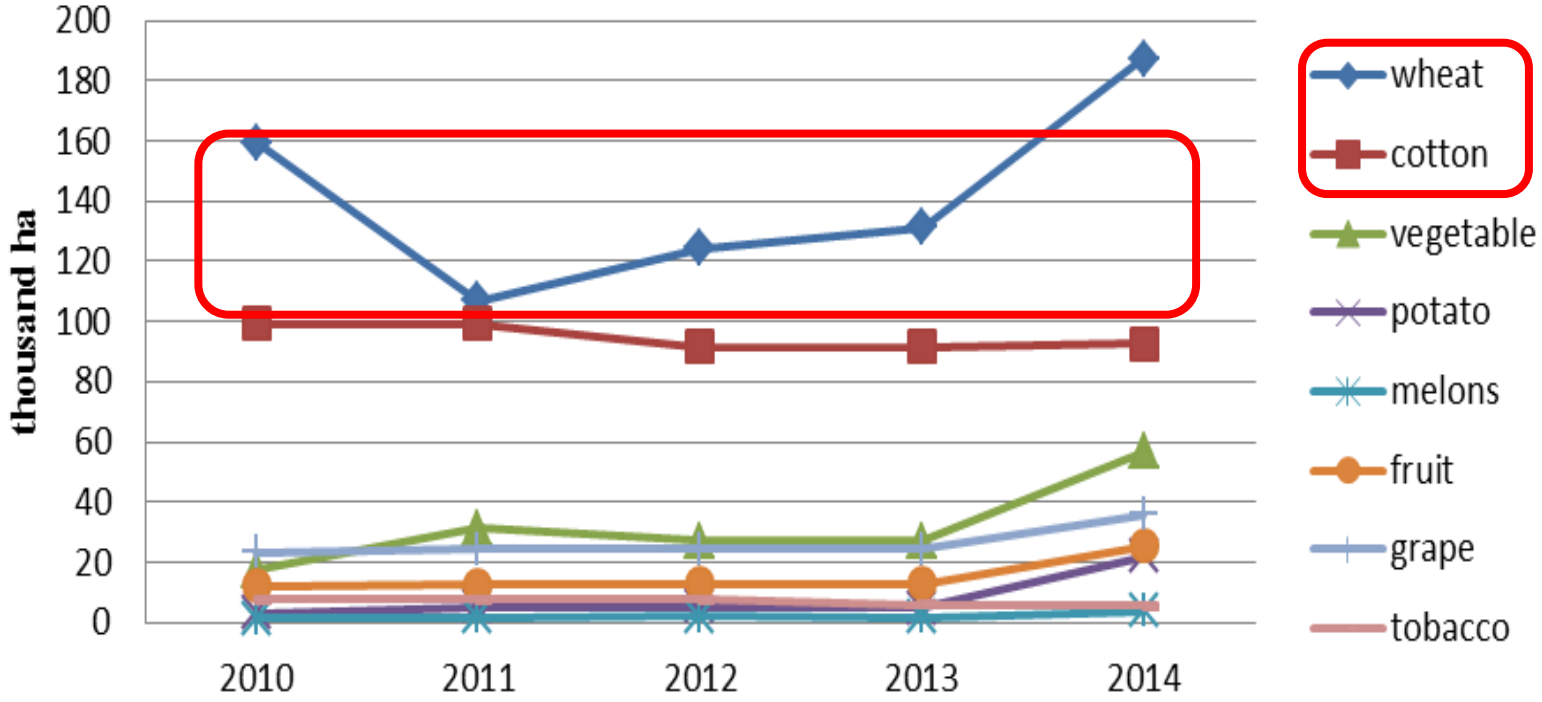


Fig.2 Changes in the area of agricultural crops in Samarkand region

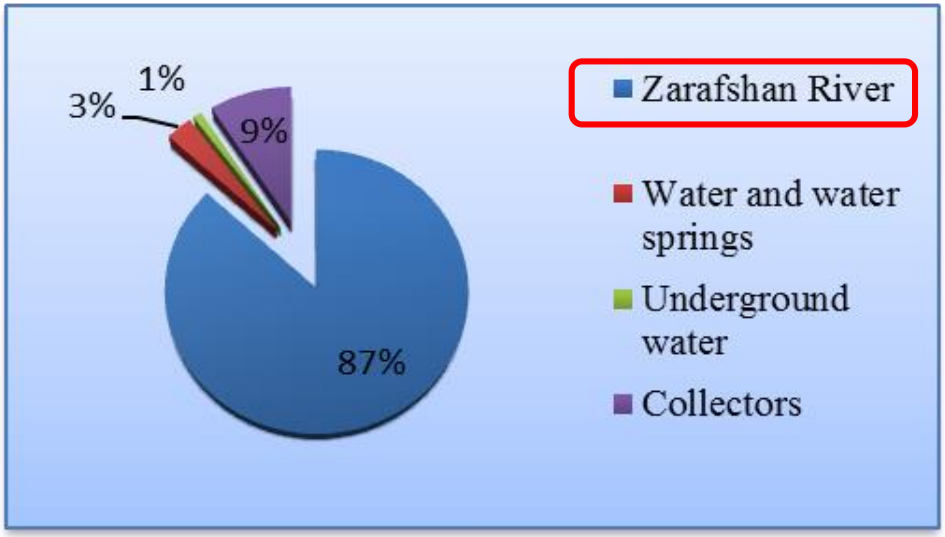


Fig.4 Water sources used in agriculture for Samarkand region, %

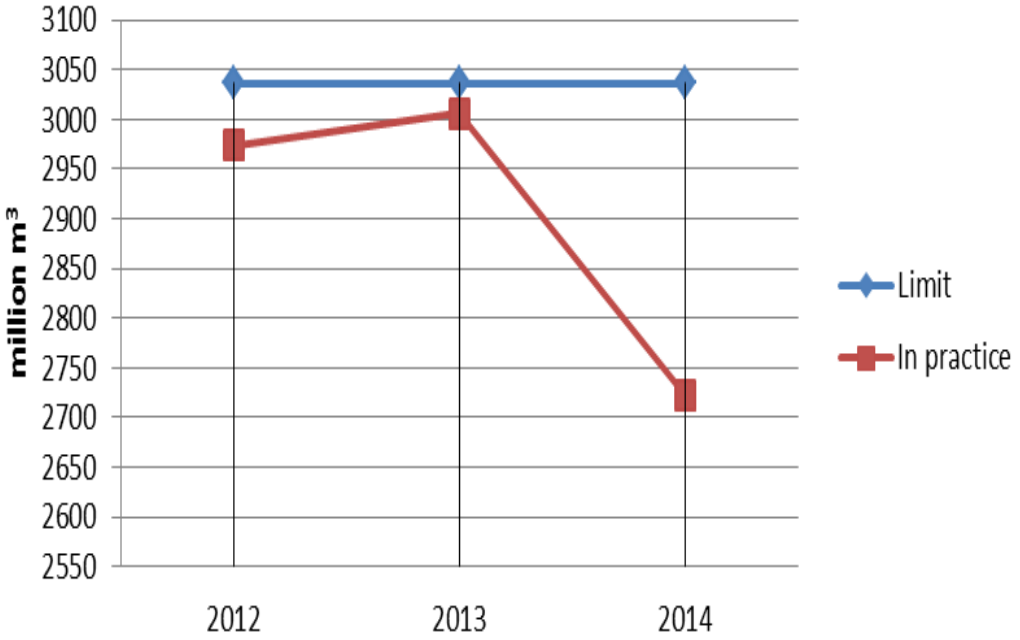


Fig.5 Samarkand region, the status of water resources in agriculture

Table 3. The changes in the number of farms and the size of a land estate of one farmer which resulted from optimization in the regions of Samarkand province

№	Regions	Before optimization (1.10.2010 survey)		After optimization (1.01.2014 survey)		Difference (+,-)	
		Overall number of farms	Average land area in ha	Total number of farms	Average land size, ha	General number of farms	Average size of lands, ha
1	Bulungur	1180	29.3	1129	32.0	-51	2.7
2	Jomboy	447	66.2	595	53.7	148	-12.5
3	Ishtikhon	707	55.5	597	70.3	-110	14.8
4	Kattakurgan	539	107.7	506	115.4	-33	7.7
5	Narpay	388	69.9	378	81.7	-10	11.8
6	Nurobod	432	181.2	416	180.5	-16	-0.7
7	Oqdarya	577	38.9	563	42.8	-14	3.9
8	Payariq	668	84.3	667	86.9	-1	2.6
9	Pasdargom	941	56.6	893	64.0	-48	7.4
10	Pakhtachi	404	54.8	357	72.9	-47	18.1
11	Samarkand	547	28.2	483	34.0	-64	5.8
12	Taylak	833	14.5	708	19.5	-125	5.0
13	Urgut	855	34.4	829	38.3	-26	3.9
14	Koshrabot	286	63.1	267	84.1	-19	21.0
	Total	8804	56.4	8388	62.5	-416	6.1

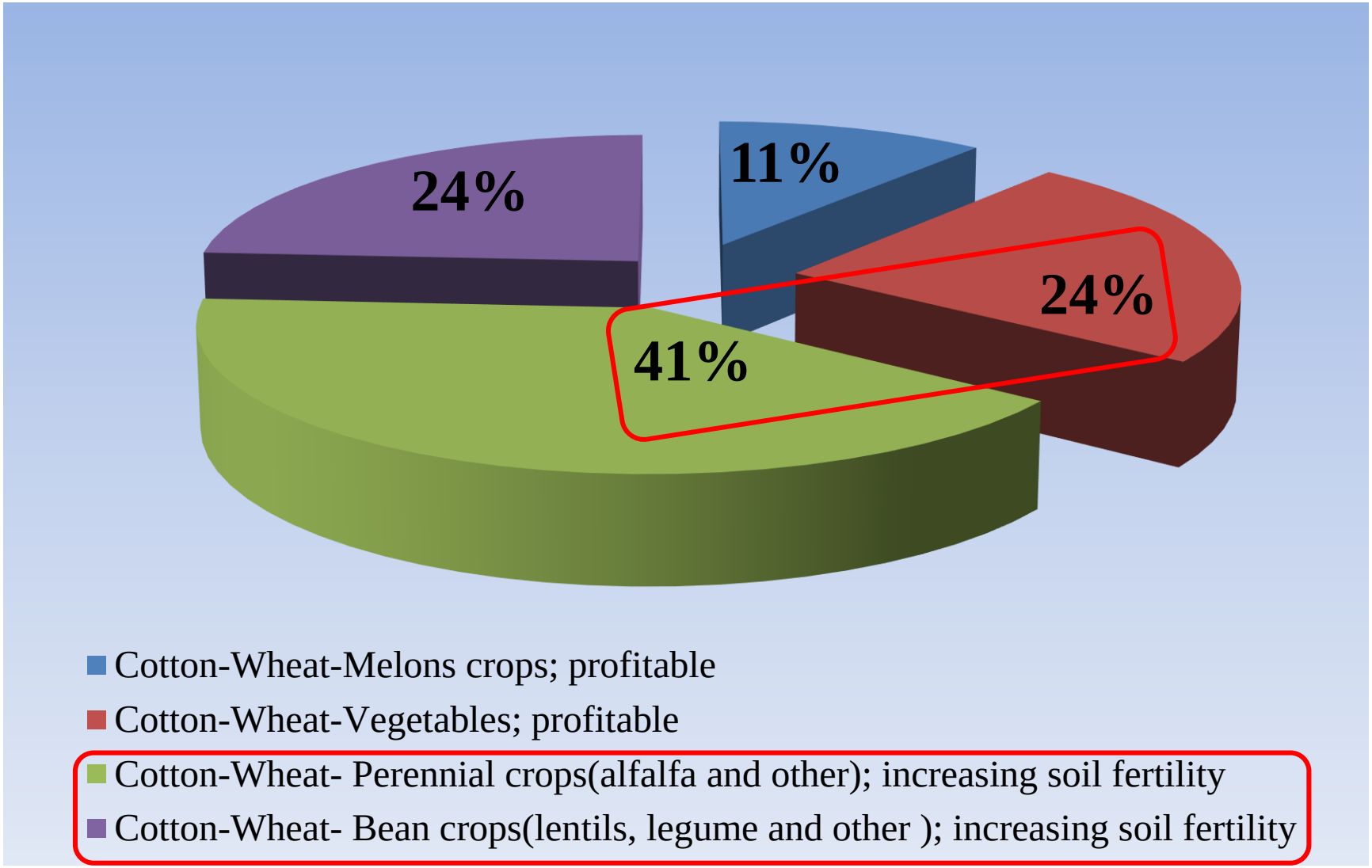


Fig.9 To choose of crops cultivation by farmers (by 37 farmers)
(If you have the opportunity to choose which crops would you like to be planted? What for?)

The quality values of soils of lands in Samarkand*, in thousand ha

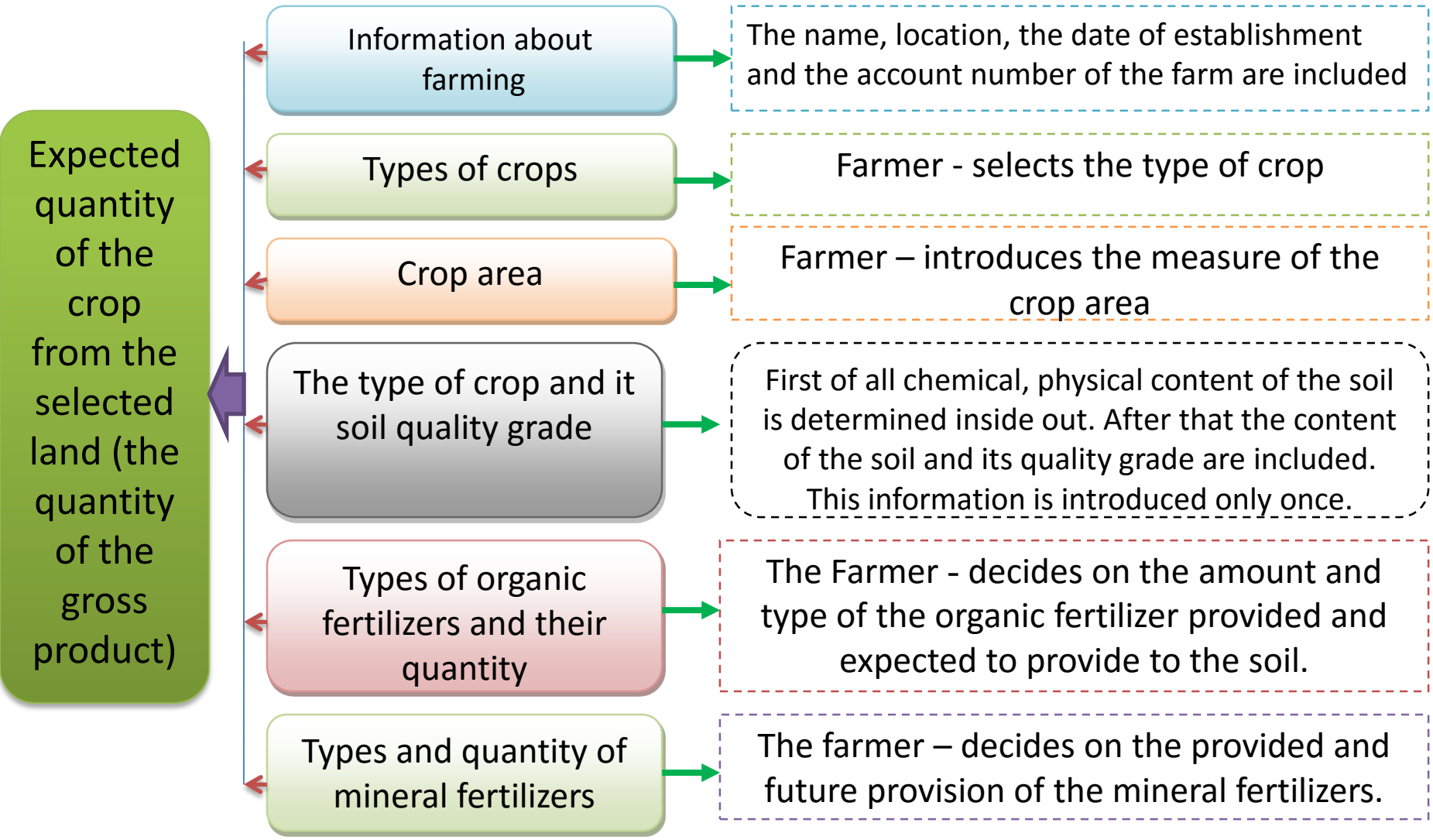
№	Region	Eroded lands		Below the average quality		Average quality lands		Good lands		The highest quality lands		Total	Average score
		1 type	2 type	3 type	4 type	5 type	6 type	7 Type	8 type	9 type	10 type		
		Quality of locality bal											
		0-10	11-20	21-30	31-40	41-50	51-60	61-70	71-80	81-90	91-100		
1	Samarkand	-	41	2044	29478	72263	89756	57187	38321	16770	547	306407	57

*Source: Statistical data of Samarkand (2008 year)

Table 6: Economical figures indicating the trends in wheat and cotton cultivation of the farms

The trends	Yield, 1000 kg	Water, m^3/ha	Or_fertilizer, kg/ha	N_fertilizer, kg/ha	Fuel, kg/ha	Labor, person-hour/ha
I	Cotton					
Mean	2749.1	8022.9	2210.2	622.3	230.6	1463.8
Max	4000	9800	3830	735	263	1944
Min	2100	6450	1130	530	205	1127.8
Median	2700	7750	1960	650	227	1431.6
StevD	406.0	1153.	736.9	61.9	17.0	223.1
Coef.Var	0.148	0.144	0.333	0.099	0.074	0.152
II	Wheat					
Mean	3970.8	5461.7	1272.3	468.3	106.2	137.2
Max	5500	6800	3500	550	115.8	148
Min	2500	3700	500	370	96.4	115
Median	4000	5600	1200	470	106.7	138
StevD	743.2	834.0	588.5	48.0	4.3	7.5
Coef.Var	0.187	0.153	0.463	0.103	0.041	0.055

The bio cycle of the soil fertility and its effect on the crops.



continuation