5. SOIL SURVEY

5.1 General Information

Soil is a medium, providing plants with moisture and nutrients. Therefore, crop yields to great extent depend on its properties. Strategy of agricultural production, use of water resources, salinity control and soil fertility management are based on knowledge of soil properties.

Expert of WARMAP Project, M. Armitage, have proposed to use for soil analyses composite soil samples, as appropriate methodology of agricultural monitoring. According to the recommendations of the project, soil samples were taken with soil auger from 0-30cm deep and at five points on each sample field, one at the center and four at the corners marked on a field sketch. Enumerator prepared a composite sample from the five samples in each field and after packing and labeling samples were sent to the Central Chemical Laboratory of sub-project WUFMAS at SANIIRI, Tashkent, for physical and chemical analyses.

In 1996, 1997 and 1998 the composite soil samples were collected once in a year (in April-May). In 1999 the number of sample fields was reduced to 18 fields only and soil samples were taken from 0-30 and 30-60cm deep at five points on each sample field, but without preparing of composite samples. Soil samples were taken from 360, 182, 120 and 18 sample fields in 1996, 1997, 1998 and 1999 respectively.

Soil profiles were described in the field, penetrometer readings were taken and soil texture was assessed by feel. Undisturbed soil cores were taken at 25 and 70 cm from soil pits dug in the center of every WUFMAS fields during 1996 – 1997. These cores were returned to the Central Laboratory and used for measure bulk density and moisture relationships (by pressure membrane), and sub-samples were used for measurement of texture, pH and EC.

Number and type of laboratory soil analyses and measurements are shown in Table 5.1.

Table 5.1 Number and Type of Analyses

Measurements	Years			
	1996	1997	1998	1999
On disturbed and composite soil samples				
EC1:5	772	162	217	273
EC1:1		58	217	284
ECe		220	217	274
pH1:5		162		
TDS	767		217	68
HCO3	566			
Cl	532		217	80
SO4	558			
Ca	532			
Mg	532			
Na+K	532			
Humus (Organic C)	532		217	89
N (N-NO3 и N-NH4)	227		217	89
P	227		217	89
K	227		217	89
Cu	226		217	
Mn	226		217	

Table 5.1 Continued….

	1997	1999
On undisturbed soil cores		
Bulk density, g/cm^3	447	55
Soil moisture at pF 4.2, 3.5, 3.0, 2.5, 2.0, 1.7	447	58
Soil texture	447	58
AWC, %	447	54
Penetration resistance	1787	59

5.2 Soil Profiles and Moisture Characteristics

Pedogenic processes in the different zones of he region depend on location above sea level and climate and hydrogeological conditions. Colluvial soil was formed in the mountain and piedmont zones as a result of thousand years of aeoliation process. In foothill zones pedogenic process was a result of both aeoliation and alluviation. In the piedmont zones soil profiles are relatively uniform. Soils in the middle reaches of the basin are more stratified and in the lower reaches they have very different texture. The above description can be confirmed by the data on soil profiles provided in Table 5.2. The average number of soil horizons in the top one metre of described profiles decreases with elevation. In farms, located on the upper reaches of Syrdarya river with elevation 954-873 mamsl, it is 1.15. In the middle reaches (Syrdarya oblast, Uzbekistan and South Kazakhstan oblast with elevation 257-280 mamsl), it is 1.55 –1.8. In the lower reaches (Kzyl Orda oblast, Kazakhstan with elevation 117.5 mamsl it is 1.7 – 1.8.

The same pattern of soil horizonation is observed along Amudarya river: in Tadjikistan at elevation 425 mamsl the number of horizons is 1.3, in Khorezm oblast of Uzbekistan at 90 mamsl it is 1.6, and in Karakalpakstan at 75-80 mamsl it is 2.1. Difference of soil texture in the horizons 0-30 and 70cm additionally proves soil non-uniformity (see Table 5.2).

Field measurements of soil penetration resistance in the horizons 0-50 and 70 cm confirm the non-uniformity of soil profiles as well. Maximum and minimum reading within the same farm can differ by as much as a factor of 10 times (Table 2). In many cases maximum penetrometer readings were observed on the depth 20 - 30 cm.

Within the range of possible measurements 0-3000 kN/m^2, all penetrometer readings were distributed within three classes: “loose soil” <500 kN/m^2, “moderately compact soil” 500–1500 kN/m^2, and “compact soil” >1500 kN/m^2.

In Tadjikistan 33 percent of surveyed profiles have penetrometer readings in the “loose” range, that of in Mary oblast of Turkmenistan and Surkhandarya oblast and Golodnaya Steppe (old irrigated zone) of Uzbekistan is 25% and 20% respectively.

Majority of surveyed profiles have penetrometer readings in the “moderate” range, in Kazakhstan 80 percent, in Kyrgyzstan 82 percent, in Tadjikistan 67 percent, in Turkmenistan 75 percent, in Uzbekistan 58 percent.

The most impenetrable soils (35-50 percent) were found in Bukhara, Surkhandarya, Khorezm oblasts and Karakalpakstan, Uzbekistan. Penetrometer readings show the existence impermeable soil layers and can be used as a basis for selection of appropriate measures for improvement of physical and moisture characteristics of soil in order to improve land productivity in certain conditions.

Dense horizons may occur in the soil profile due to:

A) development of plough pan;
B) heavy soil texture;
C) existence of consolidated layer of gypsum and carbonates.

The basic patterns of soil profiles compaction are shown in Figure 5.1, Appendix I 5.1 and I 5.2.

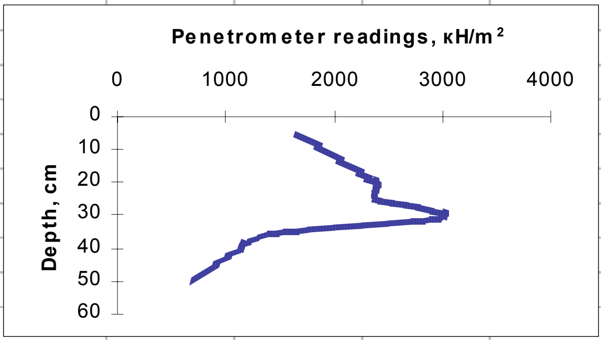
Table 5.2 Type of Soil and Textural Uniformity of Soil Profiles by Oblasts and Sample Farms

Republic, Oblast	Farm code	Elevation (mamsl)	Soil type	Number of soil horizons in top one metre (average by 20 fields)	Percentage of samples in compaction class >1500 кH/m^2 In top 0-70 (0-50) cm	Percentage of fields with non-uniform soil profiles	Percentage of fields with type 1 soil profile (plough pan)
Kazakhstan							
Kzyl Orda	1.2	117 – 117.5	*Alluvial, meadow*	*1.7*	*5*	*65*	25
South Kazakhstan	3,4	257	*Meadow, sierozem with loess subsoil*	*1.8*	*35*	*25*	85
Kyrgyzstan							
Chu	9,10	873 - 954	*Dark sierozem*	*1.15*	*28*	*67*	55
Osh	7,8	730 - 958	*Dark sierozem*	*1.5*	*5*	*25*	55
Tadjikistan	14	425	*Brown, orogenic*	1.3	0	33	
Turkmenistan							
Mary	17,18	240 - 244	*Grey, brown, desert*	*1.8*	*0*	*60*	*55*
Uzbekistan							
Surkhandarya	21,22	390	*Meadow, takyr like*	*1.2*	*45*	*40*	*20*
Syrdarya (new zone)	23,24	280	*Meadow, sierozem with loess subsoil*	*1.8*	*30*	*55*	*60*
Syrdarya (old zone)	31,32	265.5 - 267	*Meadow, sierozem on alluvial colluvial deposits*	*1.55*	*15*	*25*	*20*
Khorezm	25,26	90	*Meadow and swampy meadow, alluvial*	*1.6*	*40*	*55*	*30*
Karakalpakstan	27,28	75 - 80	*Meadow and swampy meadow, alluvial*	*2.1*	*35*	*40*	*10*
Bukhara	35,36	230	*Meadow and swampy meadow*	*1.35*	*50*	*40*	*45*

Figure 5.1 Typical Soil Profiles with Plough Pan

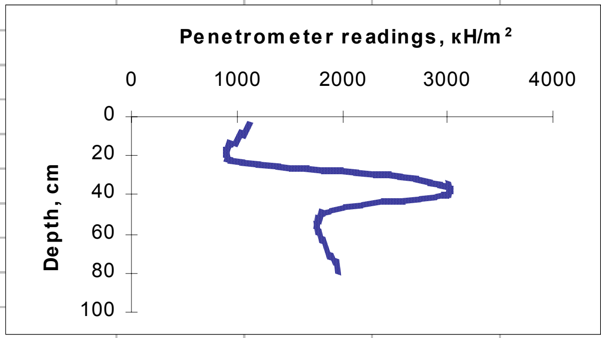
Kazakhstan

Farm 4, field 1



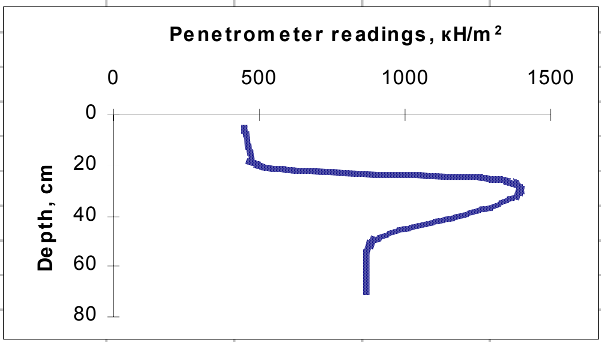
Kyrgyzstan

Farm 8, field 4



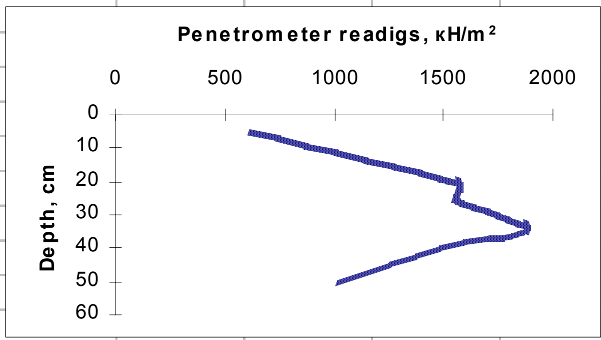
Turkmenistan

Farm 17, Field 6



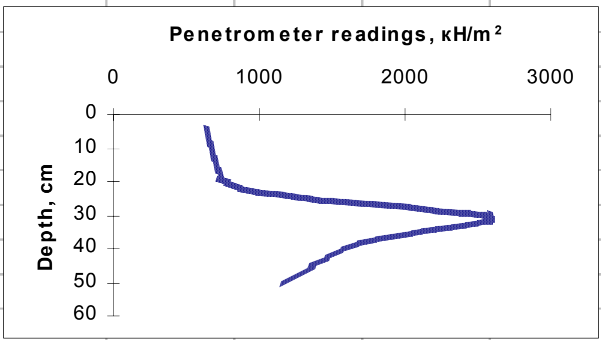
Uzbekisan

Farm 23, field 2

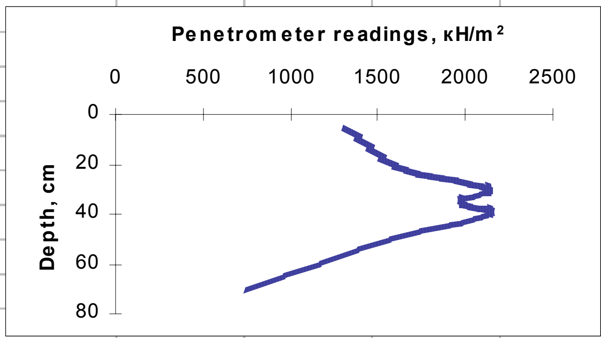


Uzbekistan

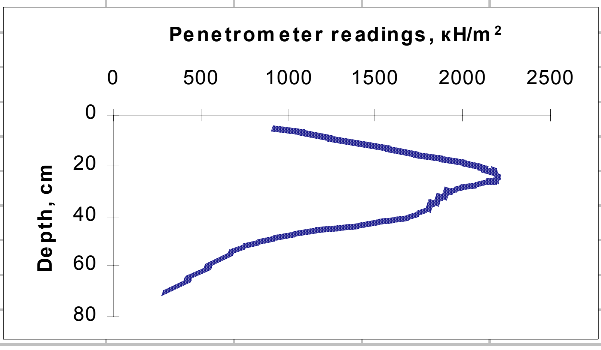
Farm 24, field 6



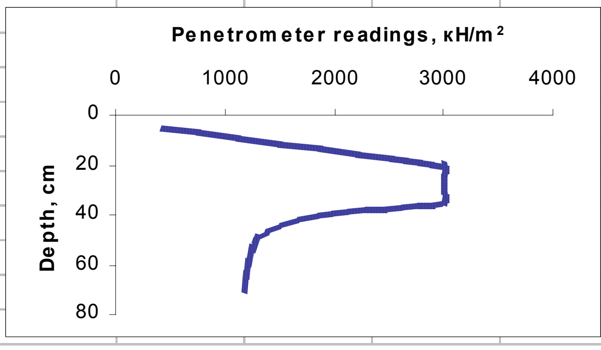
Farm 25, field 2

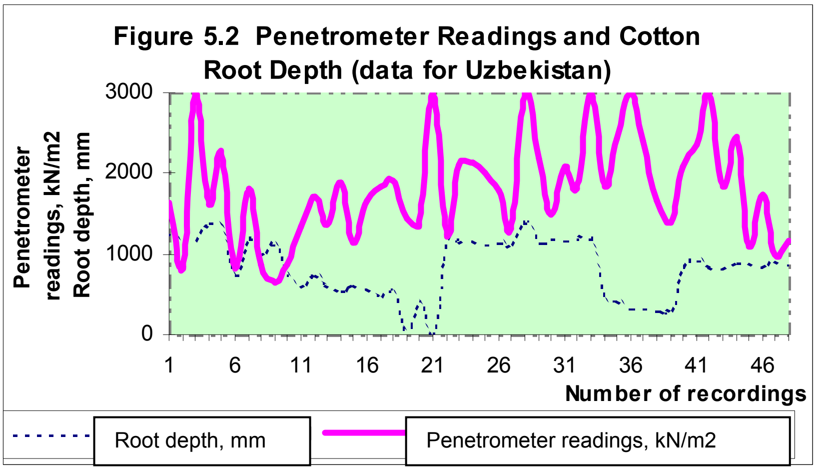


Farm 26, field 10



Farm 35, field 5





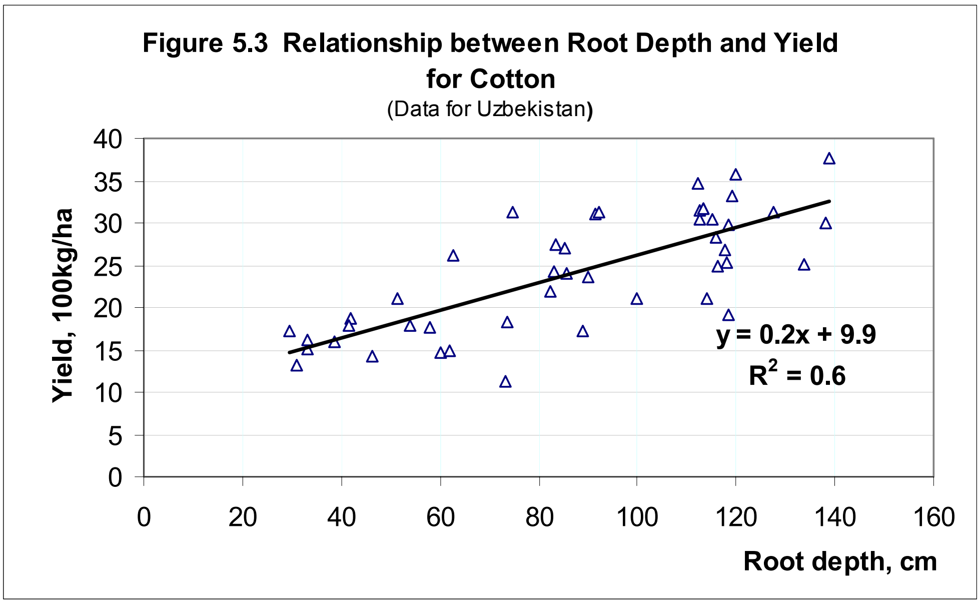


Table 5.3. Correlation Matrix between Some Indices by Sample Plots and Fields

	Max root depth, cm	*Yield from field, 100kg/ha*	*Bulk density, g/cm³*	*ECe, dS/m*	*Yield from sample plot*
Max root depth, cm	1				
Yield from field, 100kg/ha	0.46	1			
Bulk density, g/cm³	-0.10	0.21	1		
ECe, dS/m	-0.30	-0.40	-0.16	1	
Yield from sample plot	0.34	0.85	0.29	-0.28	1

There are three main soil compaction types:

Type I – plough pan, man-made compaction, is formed due to many years ploughing to the same depth. The majority of such cases was observed in South Kazkhstan oblast (85 percent of fields), in Syrdarya oblast of Uzbekistan (60 percent), in Kyrgyzstan (55 percent), in Turkmenistan (55 percent), in Bukhara oblast of Uzbekistan (45 percent), (see Table 5.5). Plough pan is formed at 30-50cm deep and can be destroyed by ripping or sub-soiling (down to 70cm).

Type 2 – compaction increasing with depth, often indicating the presence of gypsic or calcrete horizons. It is not so common in the region (no more than 35 percent of fields) and observed in Kzyl Orda oblast, Kazakhstan and Syrdarya oblast (farms 23, 24), Uzbekistan.

Type 3 – compaction decreasing with depth is observed in Karakalpakstan (60 percent of fields), Surkhandarya and Bukhara oblasts (45 and 35 percent respectively). Ripping and sub-soiling along with application of significant amount of organic fertilizer can improve such soil.

Yield losses due to the presence of plough pan confirm that cotton yield depends on root depth, which in turn depends on soil compaction (see Figure 5.2, Figure 5.3 and Table 5.3).

Sedimentation method was used for analyses of soil texture. For interpretation of results both local classification by Kachinsky and FAO classification were used.

International system of soil texture vary from local system mainly in defining:

1. the upper size limit of “clay” particles as 0.002mm (in local classification this limit is 0.001mm);
2. textural classification of soils is based on two-dimensional variation, two out of sand (particles >0.05mm), silt (particles 0.05-0.002mm) and clay < 0.002 (the third, being defined by the sum equal to 100 percent). Local classification is based on sum of fraction of “physical clay”: [(0.005-0.001)+(<0,001)] mm.

On average soil samples of the region contain 25 percent of sand fraction, 53 percent of silt fraction and 22 percent of clay faction. High percentage of silt defines the main chemical and physical properties of local soils, as for example low value of CEC (cation exchange capacity), low content of organic matter etc.

Soil samples for soil texture analyses were taken from two horizons: topsoil and subsoil. Textural classification of 445 soil samples, based on the FAO (USBR) textural triangle, allows distributing all samples as following:

- 47 percent of soil samples are silt loam (ZL);
- 19 percent are loam (L);
- 14 percent are silty clay loam (ZCL);
- 6 percent are sandyloam (SL).

Number of samples (out of total 445) classified as of silty clay (ZC), clay loam (CL), clay (C), loamy sand (LS) and silt (Z) is very small, 18, 19, 13, 4 and 4 samples respectively.

According to the local classification (by Kachinsky) distribution of 445 soil samples is as following:

- 37 percent of soil samples are medium loam;
- 20 percent are heavy loam;
- 16 percent are light loam;
- 9 percent are light clay;
- 7 percent are loamy sand;
- 11 percent are heavy and medium clay, consolidated sand.

Comparison of textural classes, defined by **USBR** and local classification, showed that over 50 percent of cases international **silt loam (ZL)** and **loam (L)** correspond to local **medium loam** and **silty clay loam (ZCL)** corresponds to local **heavy loam.**

Undisturbed soil cores were taken at 25cm (topsoil – A horizon) and 70cm (sub-soil – B horizon) from soil pits to measure *bulk density.* Average values of bulk density vary in the range from 1.34 to 1.52 g/cm^3, with minimum values of 1.1-1.3 g/cm^3 and maximum values of 1.42-1.74 g/cm^3 (see Table 5.4).

The lowest values of bulk density in horizon A (1.27 g/cm^3) were recorded in Kzyl Orda oblast, Kazakhstan, the highest ones (1.53-1.57 g/cm^3) were recorded in Mary oblast, Turkmenistan (80-90 percent of cases), Surkhandarya oblast (54-63 percent of cases), Khorezm oblast (53-55 percent) and Karakalpakstan (70 percent), Uzbekistan.

In the upper and middle reaches of Syrdarya river (Kyrgyzstan, South Kazakhstan oblast, Syrdarya and Bukhara oblasts of Uzbekistan) bulk density is 1.41-1.47 g/cm^3 and it is almost the same in both A and B horizons. In Kzyl Orda oblast the value of bulk density is higher in B horizon, and in Karakalpakstan it is higher in A horizon.

So, more heavy soils are found in specific conditions of desert zone (Turkmenistan, Surkhandarya oblast of Uzbekistan) and in the lower reaches of Syrdarya and Amudarya rivers.

From the local experience cotton yield losses relative to potential yield in relation to the bulk density of topsoil is evaluated as following:

Bulk density	**Yield losses**
1.4 g/cm^3	10 -15 %
1.5 g/cm^3	20-30%
1.6 g/cm^3	30-50%
>1.6 г/cм^3	40-60%.

In farms of South Kazakhstan oblast penetrometer readings are varied in the range from 666 to 3000 kN/m^2 with the range of bulk density values 1.31-1.71 g/cm^3. Existence of relationship between penetrometer resistance and soil bulk density (with correlation coefficient R^2=0.5) proves that penetrometer can be used for indirect measurements of soil bulk density in the field with the uniform texture of soil profile (Figure 5.4).

Figure 5.4 Relationship between Penetrometer Readings and Bulk Density Farms 3 and 4, South Kazakhstan Oblast

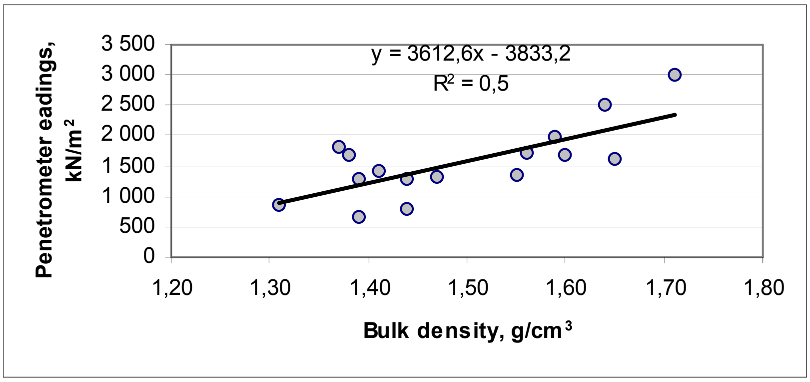


Table 5.4 Distribution of Soils in Sample Farms by Textural Classes (as percentage of total number of sample fields)

Farms	Textural class																						Bulk density, g/cm³	
	C		CL		SCL		ZC		ZCL		ZL		L		S		SL		LS		Z			
Horizon	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
1,2	20	25	15	0	5	0	35	30	15	10	10	25	0	10	0	0	0	0	0	0	0	0	1.27	1.41
3,4	0	0	0	5	0	0	0	0	0	0	80	65	20	30	0	0	0	0	0	0	0	0	1.47	-
7,8	5	14	14	5	4	14	10	10	24	14	10	19	5	5	5	5	24	10	0	5	0	0	1.43	1.4
9,10	0	0	20	5	0	0	0	5	0	5	35	40	45	35	0	0	0	10	0	0	0	0	1.46	1.46
14	0	0	0	0	0	0	0	0	0	33	0	0	100	33	0	0	0	0	0	33	0	0	-	-
17,18	0	0	5	0	0	0	0	0	0	0	25	45	55	25	0	0	15	30	0	0	0	0	1.57	1.62
21,22	0	0	5	5	0	0	0	5	60	70	20	10	10	10	0	0	5	0	0	0	0	0	1.53	1.53
23,24	0	0	5	0	0	0	0	0	10	20	30	45	45	30	0	0	10	0	0	0	0	5	1.45	1.49
25,26	0	0	5	0	0	0	0	0	10	25	60	50	25	20	0	0	0	0	0	0	0	5	-	-
27,28	0	0	0	0	0	0	0	10	5	15	85	55	5	0	0	0	5	5	0	10	0	5	1.54	1.41
31,32	0	0	10	0	0	0	0	0	0	0	80	75	0	25	0	0	0	0	0	0	10	0	1.41	-
35,36	0	0	10	0	0	5	0	0	15	15	75	70	0	10	0	0	0	0	0	0	0	0	1.44	1.40

Soil moisture characteristics were measured in undisturbed top- and subsoil samples using pressure membrane apparatus in the SANIIRY laboratory. Soil moisture content was measured by weighing, after stabilising the soil samples at a range of soil suction pressures equivalent to pF 2.0, 2.5, 3.5, and 4.2. These data can be used for irrigation scheduling, soil leaching recommendations and for estimation of available soil moisture capacity.

Quantitative indices of soil moisture content (full saturation, field capacity, soil moisture content at permanent wilting point etc.) are necessary for irrigation scheduling. According to the international methodology it is necessary to maintain available soil moisture content (AWC). AWC is the difference between moisture content at field capacity **(pF=2)** and permanent wilting point **(pF=4,2)**. Different crops can use only certain part of AWC depending on its depletion factor. Values of depletion factor are different for different crops and are available in special reference books. Moisture content at field capacity **(pF=2)** and permanent wilting point **(pF=4,2),** AWC and soil porosity were defined for each soil type.

Figure 5.5 Moisture Characteristics of Typical Soils

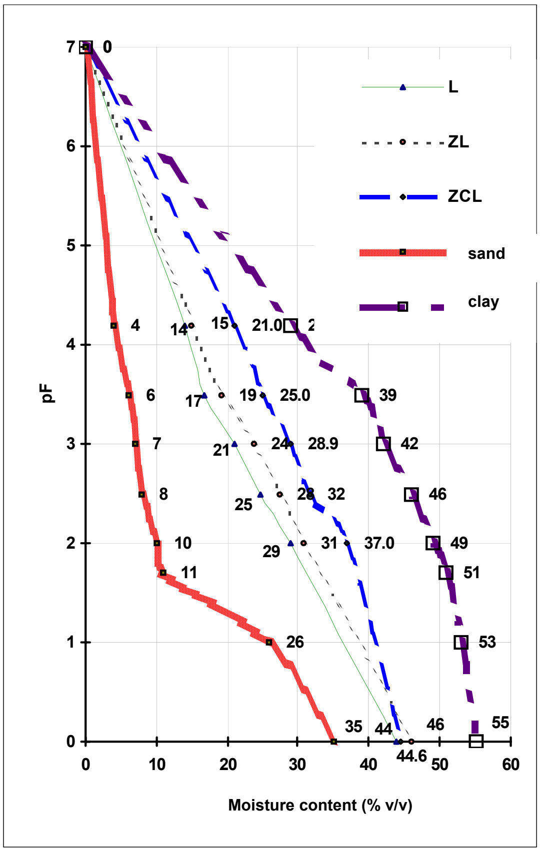


Table 5.5 Relationship between Soil Moisture Content and pF

Soil texture (FAO)	No of sam-ples	Soil moisture at different soil suction pressure:								AWC, % (pF2-pF4,2)	Local (70 % from FC)	FAO (65 % from AWC)
		kPa	1000000	1580	316	100	32	10	1			
		pF	7	4,2	3,5	3	2,5	2	0			
Loam (L)	76*)		0	14	17	21	25	29	44	15	20,3	19,3
Silt loam (ZL)	169*)		0	15	19	24	28	31	46	16	21,7	20,6
Silty clay loam (ZCL)	41*)		0	21	25	28,4	32	37	44,6	16	25,9	26,6
Sand (S)	-**)		*0*	*4*	*6*	*7*	*8*	*10*	*35*	*6*	*7*	*6,1*
Clay (C)	-**)		*0*	*29*	*39*	*42*	*46*	*49*	*55*	*20*	*34,3*	*36*

*) based on WUFMAS database
**) data from J.R.Landon Booker Tropical Soil Manual

All these indices were used in the project for irrigation scheduling using daily water balance for each sample field.

All the above described data were entered in the WUFMAS database and it is allows to maintain optimal irrigation schedules. Depending on soil texture and bulk density soil moisture characteristics vary in a wide range. Typical soil moisture characteristics for the whole region are shown in Figure 5.5 and Table 5.5.

In soils with different texture average value of porosity is 45.6%, with a range from 43.2 to 50.4 percent (on volume per volume basis). Minimum value of porosity is in the range 34.8-46.8 percent and maximum is in the range 51.3-58.8 percent.

Soil moisture content at field capacity (FC) (pF = 2.0) is on average 31.9 percent (volume per volume) with the range from 16 to 39.2 percent, depending on soil texture (from 12 percent for silty soils (Z) to 27 percent for clay loam (CL)).

Soil moisture content at permanent wilting point (PWP) (pF = 4.2) is on average 16.2 percent with the range from 5.7 percent for sandy loam (SL) to 22.2 percent for silty clay (ZC). Minimum values of PWP are in the range from 3.9 percent for silt (Z) to 13 percent for silty clay (ZC). Maximum values are in the range from 7 percent for loam (L) to 31.6 percent for silty clay loam (ZCL).

Available moisture content (AWC) is on average 15.6 percent with the range from 10.3 percent for loamy sand (LS) to 19 percent for sandy clay loam (SCL).

Minimum AWC values for different soil texture are 8.1-13 percent and maximum ones are 18.5-26.3 percent.

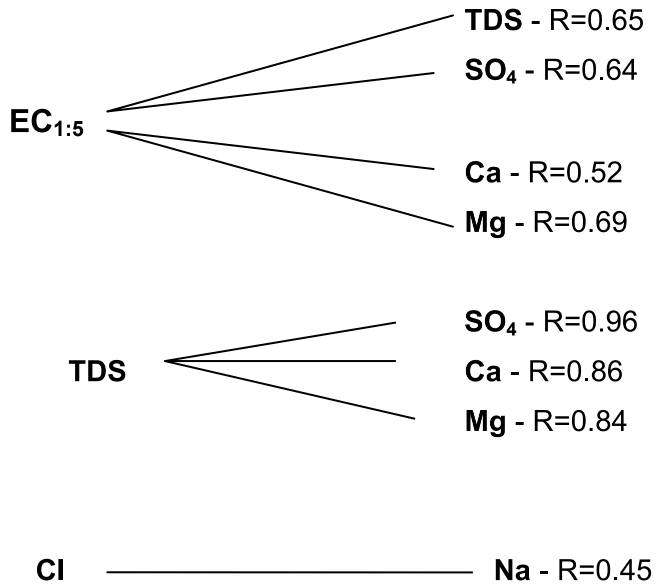
5.3 Soil Chemical Composition and Salinity

Chemical composition of 1:5 water extract shows a presence in the soil soluble ions: HCO_3, CL, SO_4, Ca, Mg, Na и K.

According to the analyses the average value of pH is 7.65, with the range of minimum and maximum values 6.8-7.4 and 7.6-8.74 respectively.

Content of ions SO_4 and Ca is the highest in the soils of the region. Content of SO_4 is in the range 1.81-20.32 me/100g, that of Ca is 0.75-14.22 me/100g, Mg is 0.49-24.42 me/100g, Na is 0.34-19.44 me/100g, Cl is 0.42-9.86 me/100g. Content of K is very poor 0.02-2.49 me/100g. Content of total dissolved solids is varied in the range from 0.22 to 3.04 percent.

Correlation matrix between indices of soil chemical composition shows presence of the following relationships:



The most close relationships between TDS and content of SO_4, Ca, Mg, are associated with predominance of these ions in local soils.

It is clear, that presence of Na Cl increases to some extent the value of pH in water extract and conversely cations of calcium decrease pH.

Electrical conductivity is an integral index of soil salinity and its value to great extent depends on content of ions Mg and SO_4 or $MgSO_4$.

The measurement of electrical conductivity is used for assessment of degree of soil salinity. EC is measured in a 1:5 water extract ($EC_{1:5}$) with subsequent adjustment to the conductivity of a saturation extract of the soil (ECe). ECe is the FAO criterion of salinity (see Table 5.6). So a factor **K** is required to adjust from $EC_{1:5}$ to ECe.

For calibration of factor **K** in the equation **ECe = K * $EC_{1:5}$** the Regional Chemical Laboratory has accomplished series of special experiments and empirical calculations for the main soil types of the region. The procedure of experiments was as following: a saturated extract was withdrawn from a saturated paste of the soil under strong suction, then it was measured ECe value and $EC_{1:5}$.and $EC_{1:1}$ of the same soil samples. The results of this exercise, accomplished within the framework of sub-project WUFMAS, are provided in the Annex II.

Table 5.6 FAO (USDA) Criteria for Classification of Soil Salinity

Salinity class	EC of saturation extract of soil ECe in dS/m, at t = 25 ^{0}C	Crop sensitivity to soil salinity
None	**0- 2**	**Very sensitive** *(onion, carrot, fruits)*
Slight	**2- 4**	**Sensitive** (*tomato, lucerne, rice, maize for grain*)
Moderate	**4- 8**	**Slightly sensitive** (*beet-root*)
Severe	**8-16**	**Slightly salt tolerant** (*cereals, cotton, sugar beet*).
Very severe	**> 16**	**Salt tolerant** *(halophytes – tamarix, saltwort etc.)*

According to the results of this exercise use of a **1:1 soil water suspension** is recommended for assessment of soil salinity, but not 1:5 water extract and the following adjustment coefficients were defined:

$$\mathbf{ECe = (3,3 - 3,7)EC_{1:1}} \quad \text{and} \quad \mathbf{ECe = 4,0EC_{1:5}}.$$

The above study was accomplished only in 1999. Therefore, data from the database for period from 1996 to 1998 (with EC measurements in a 1:5 water extract) were used for evaluation of trends in soil salinity. So, for the purpose of this report EC values derived from $EC_{1:5,}$ were used, and for calculation of ECe from $EC_{1:5}$ experimental **coefficient K=4.0** was used.

Chemical composition of water extract for different conditions is shown in Figure 5.6.
Due to high content of sulphates, assessment of soil salinity type on the basis of ratio Cl/SO_4, revealed that almost all sample fields (75 percent) have sulphate type of salinity and the rest 25 percent have chloride-sulphate salinity type (see Figure 5.6 and Appendix I 5.4). All analysed soil samples contain a lot of calcium salphate, which is not a toxic salt, therefore assessment of salinity type on the basis of ratio Na/Cl in this case is more correct. It is clear from Appendix I 5.4, that evaluation of salinity type on the basis of ratio Na/Cl shows quite different results and even within one pair of farms all four types of salinity are observed. And nevertheless, it was discovered that sulphate type of salinity is predominant in Fergana Valley, chloride-sulphate and sulphate types are in Syrdarya oblast, sulphate-chloride and chloride-sulphate types are in Mary oblast of Turkmenistan, Kzyl Orda oblast of Kazakhstan and Surkhandarya oblast of Uzbekistan. Chloride type of salinity is very common in lower reaches of Amudarya river (Akhal oblast of Turkmenistan, Karakalpakstan and Bukhara oblast of Uzbekistan). Presence of significant quantity of SO_4 in soils (for example, in the middle reaches of Syrdarya river) and high moveability of chlorides are the reasons for change of salinity type **from chloride to sulphate** with leaching and backward **from sulphate to sulphate-chloride type** with secondary salinisation. Therefore, increase of soil salinity degree in these zones will mean increase of chloride content. But it is necessary to remember about certain conventionality of salinity type definition.
However, a special study and analyses are required for development of more precise prognosis.

Distribution of saline soils by WUFMAS sample farms is shown in Figure 5.7, and assessment of soil salinity degree on the basis of ECe is presented in Table 5.7 and Figure 5.8.

Figure 5.6 Chemical Composition of 1:5 Water Extract from Soil by CAR

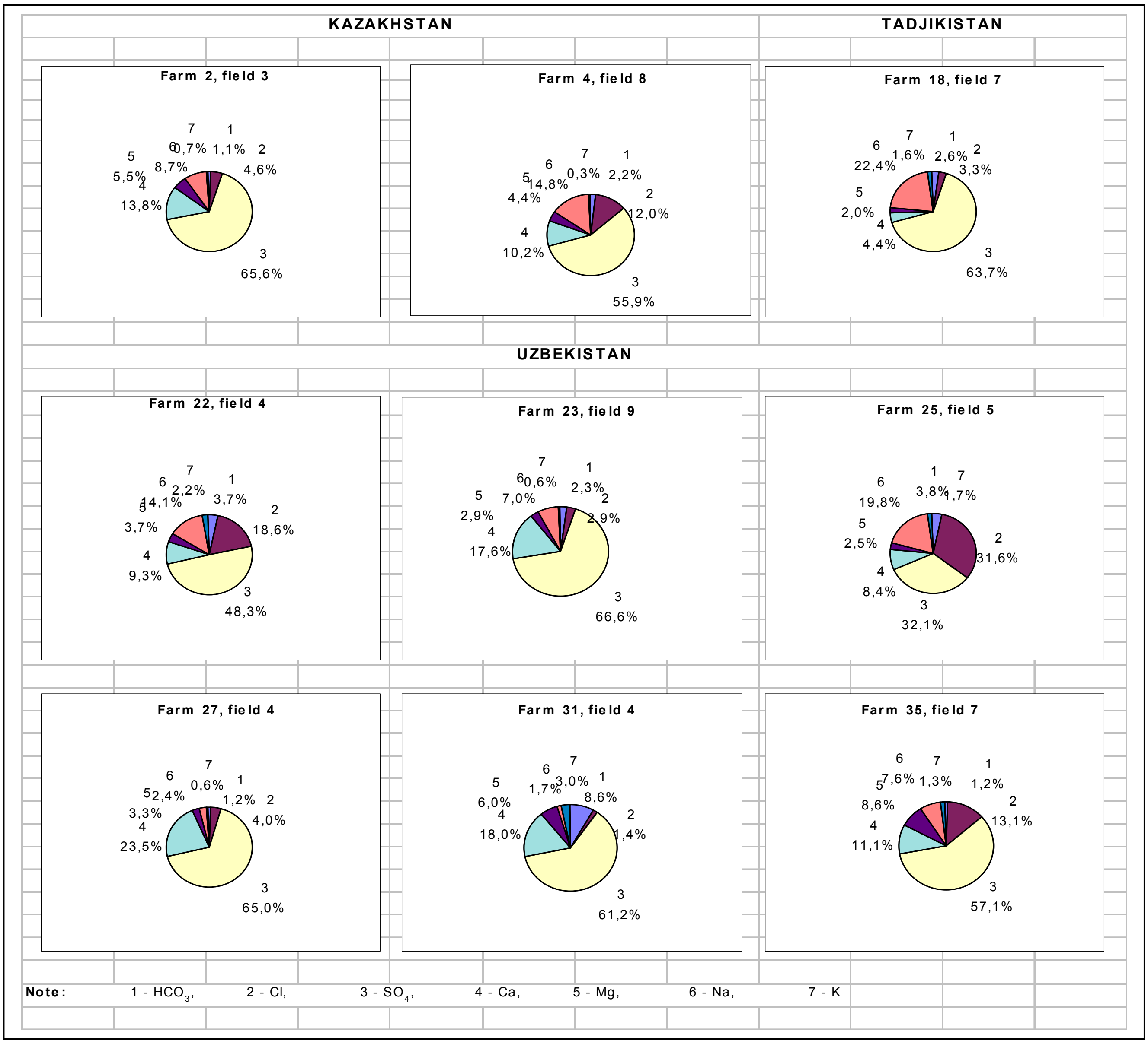


Figure 5.7 Variation of Soil Salinity Classes by Sample Fields (percentage of total number of sample fields)

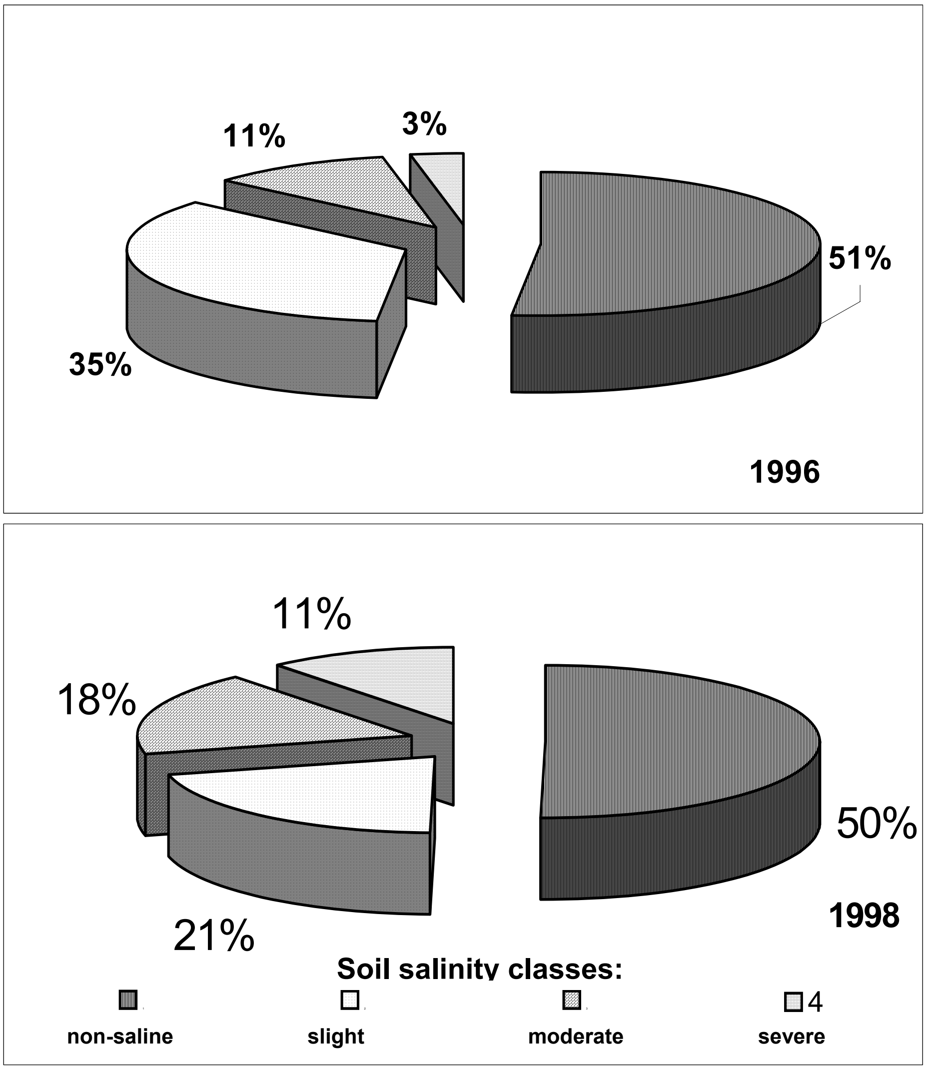
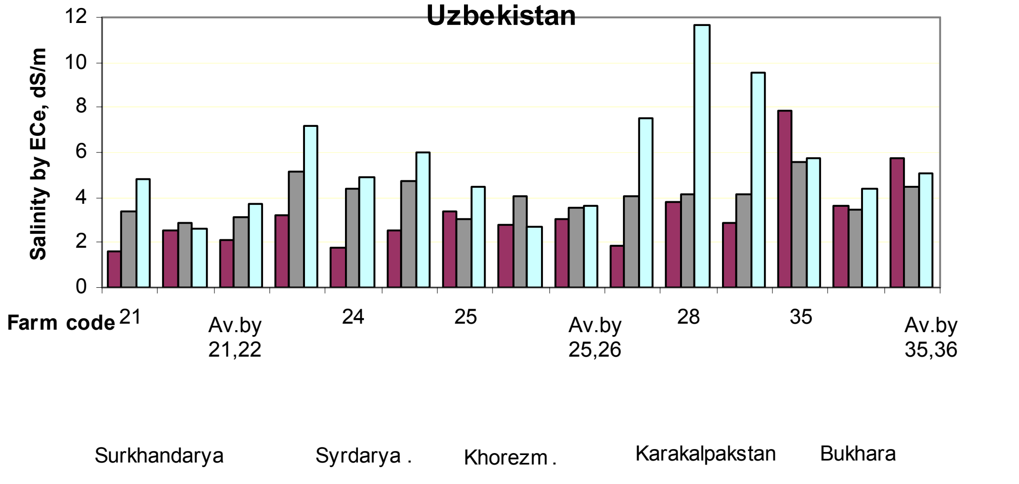


Figure 5.8 Variation of Soil Salinity by Sample Farms Uzbekistan



At the beginning of survey, spring 1996, the highest salinity degree (on average) was observed in farm 35, Bukhara oblast of Uzbekistan and farm 2, Kzyl Orda oblast of Kazakhstan (with **ECe 7 - 8 dS/m** – medium saline soils). The least saline soil was observed in farm 18, Turkmenistan **(ECe~1 dS/m)**. The rest of the farms in a plane land zone had low saline soils **(ECe = 2 - 4 dS/m).** Maximum value of ECe up to **7 - 22 dS/m** was observed on some fields.
Three years monitoring of ECe value averaged by ten sample fields showed **an increase of soil salinity degree**. Apart from farms in Karakalpakstan and Bukhara and Fergana oblasts of Uzbekistan soil salinity was within the limits of “slight” **(4 dS/m)**. In some fields in Bukhara, Kashkadarya and Surkhandarya oblasts soil salinity was higher than moderate **(ECe=8 dS/m)**. It is clear from Figure 5.9, that increase of salinity is not uniform in all fields probably due to different irrigation water supply and drainage conditions. This is well pronounced in Bukara oblast and Karakalpakstan.

Increase of salinity was recorded almost in all sample fields of Syrdarya oblast, but in Surkhandarya oblast it was observed only in some fields where drainage water with salinity up to 3g/l was used for irrigation.

From Figure 5.7 it is clear, that during 1996-1998 percentage of fields with different degree of soil salinity has changed: percentage of slightly saline soils was decreased from 35 to 21 percent, at the same time percentage of moderately and severely saline soils was increased from 17 to 29 percent. Share of severe saline soils was increased from 3 to 11 percent.

It is well-known that yield losses may occur due to soil salinity as following:
– on slightly saline soils cotton yield losses is up to 15 percent;
– on moderately saline soils it is up to 40 percent;
- on severely saline soils it is up to 60 percent.

FAO criteria is also taking into consideration crop salt tolerance: for example, yield losses of more sensible crops (tomato, pepper, onion and others) occur then salinity is more than 2 dS/m, and yield losses of salt tolerant crops (wheat, barley, cotton) occur then salinity is more than 7 dS/m (see Appendix II). However, analyses of data on relationship between yield and soil salinity in different zones of Uzbekistan (Figure 5.9) have revealed that with **moderate degree** of soil salinity (at ECe = 6 dS/m by FAO classification) and depending on soil type, depth and salinity of groundwater cotton yield losses may be 20 - 30 percent.

Figure 5.9 Variation of Soil Salinity by Sample Fields and Farms Uzbekistan

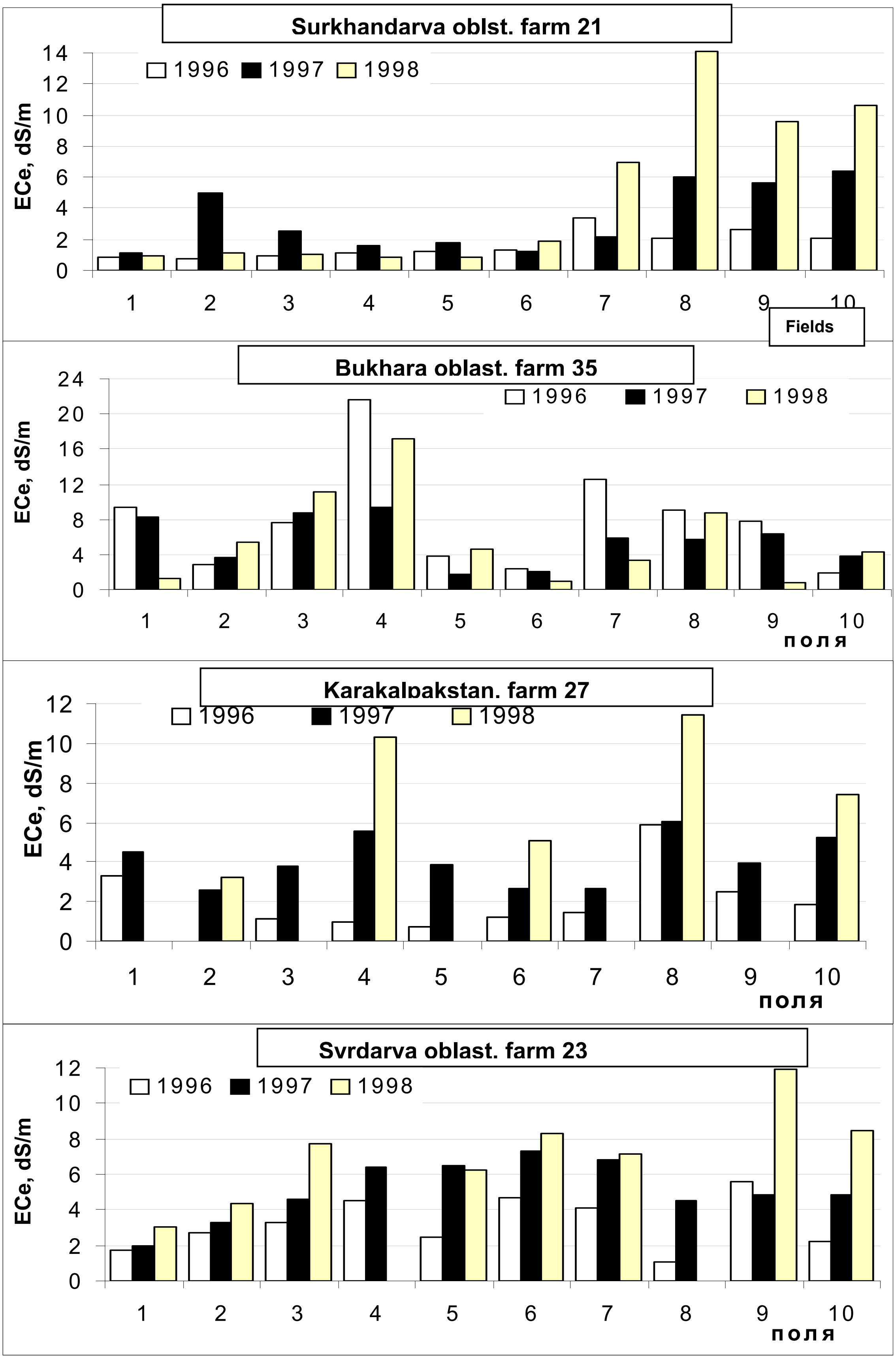


Table 5.7 Variation of Soil Salinity by Sample Farms
(average by 10 sample fields)

Farm code	Value	Republic, Oblast	ECe, dS/m 1996 spring	1997 spring	1998 spring	Variation 1996 - 1998
1	Maximum		5.84	8.76		
	Minimum		2.60	1.92		
	Average	**Kazakhstan**	3.90	3.95	n.a	
2	Maximum	**Kzyl Orda**	11.84	8.32	n.a	
	Minimum		1.84	1.96	n.a	
	Average		7.00	4.85	n.a	
	Av by farms 1,2		***5.45***	***4.40***	***n. a.***	
3	Maximum		6,00	4.60	7.20	
	Minimum		0.84	1.12	1.20	
	Average	**Kazakhstan**	1.97	2.39	3.19	62
4	Maximum	**South Kazakhstan**	6.76	4.28	7.84	
	Minimum		1.12	1.8	0.96	
	Average		3.29	2.93	3.39	3
	Average by 3,4		***2.63***	***2.66***	***3.29***	***25***
17	Maximum		4.6	4.64	13.28	
	Minimum		1,00	0.88	1,00	
	Average	**Turkmenistan**	2.86	1.89	2.85	
18	Maximum	**Mary**	1.80	2.20	3.16	
	Minimum		0.52	1.12	1.28	
	Average		0.92	1.49	2.06	123
	Av. by 17,18		***1.89***	***1.69***	***2.46***	***30***
21	Maximum		3.40	6.40	14.12	
	Minimum		0.76	1.16	0.80	
	Average	**Uzbekistan**	1.63	3.35	4.79	194
22	Maximum	**Surkhandarya**	6.28	5.6	5.64	
	Minimum		1,00	1.20	0.88	
	Average		2.52	2.85	2.60	3
	Av.by 21,22		***2.07***	***3.10***	***3.70***	***78***
23	Maximum		5.56	7.32	11.88	
	Minimum		1.04	1.96	3.08	
	Average	**Uzbekistan**	3.23	5.12	7.15	121
24	Maximum	**Syrdarya**	4.28	7.60	9.68	
	Minimum		0.80	1.96	1.92	
	Average		1.78	4.40	4.89	175
	Av. by 23,24		***2.50***	***4.76***	***6.02***	***140***
25	Maximum		6.92	6.56	8.32	
	Minimum		1.36	0.72	1.44	
	Average	**Uzbekistan**	3.38	3.06	4.52	34
26	Maximum	**Khorezm**	4,00	8.76	4.40	
	Minimum		1.72	2.56	1.36	
	Average		2.78	4.09	2.67	-4
	Av. by 25,26		***3.08***	***3.58***	***3.59***	***17***
27	Maximum		5.84	6.08	11.40	
	Minimum		0.72	2.60	3.20	
	Average	**Uzbekistan**	2.11	4.08	7.48	254
28	Maximum	**Karakalpakstan**	9.68	10.52	28.88	
	Minimum		1.76	1.40	1.80	
	Average		3.84	4.16	11.68	205
	Av. by 27,28		***2.97***	***4.12***	***9.58***	***222***
35	Maximum		21.60	9.32	17.20	
	Minimum		1.92	1.80	0.84	
	Average	**Uzbekistan**	7.89	5.54	5.78	-27
36	Maximum	**Bukhara**	9.16	6.28	12.28	
	Minimum		1.60	1.56	1.24	
	Average		3.62	3.47	4.44	23
	Av. by 35,36		***5.75***	***4.51***	***5.11***	***-11***

But at the same level of salinity there is no significant yield loss in Bukhara and Khorezm oblasts (Figure 5.10). On the one hand it can be explained by the high level of crop husbandry in these oblasts, and on the other hand by high level of relatively fresh (3-4.5g/l) ground water which dissolves concentration of soil solution and mitigates salinity stress to the crop. Correlation matrix in Annex I 5.6 confirms relationship between yield and **salinity** and annual **water supply**. It is necessary to underline that both these factors **have bigger impact on yield, than fertilizer application and nutrients content in the soil.**

Specific water supply for irrigation of cotton and leaching rates on plain land are not enough for salinity control. Total annual specific water supply to the field (in 1996-1998) on average was **2.2 – 4.8 tcm/ha**, and in Uzbekistan it was **3 tcm/ha** (Annex I 5.5). During vegetation period average specific water supply is even less by approximately 0.3 – 1.5 tcm/ha. In the conditions of high groundwater table plant receives compensation in available moisture from groundwater, but this does not prevent salt accumulation in topsoil. In such conditions soil salinity will grow year after year and yield losses will be higher and higher. Relationship between irrigation rates, total net annual water supply, soil salinity and yield are illustrated in Figure 5.11. In this figure relationships between salinity of irrigation and ground water and soil salinity are shown as well.

Figure 5.10 Relationship between Soil Salinity and Yield (t/ha) by Oblasts in Uzbekistan

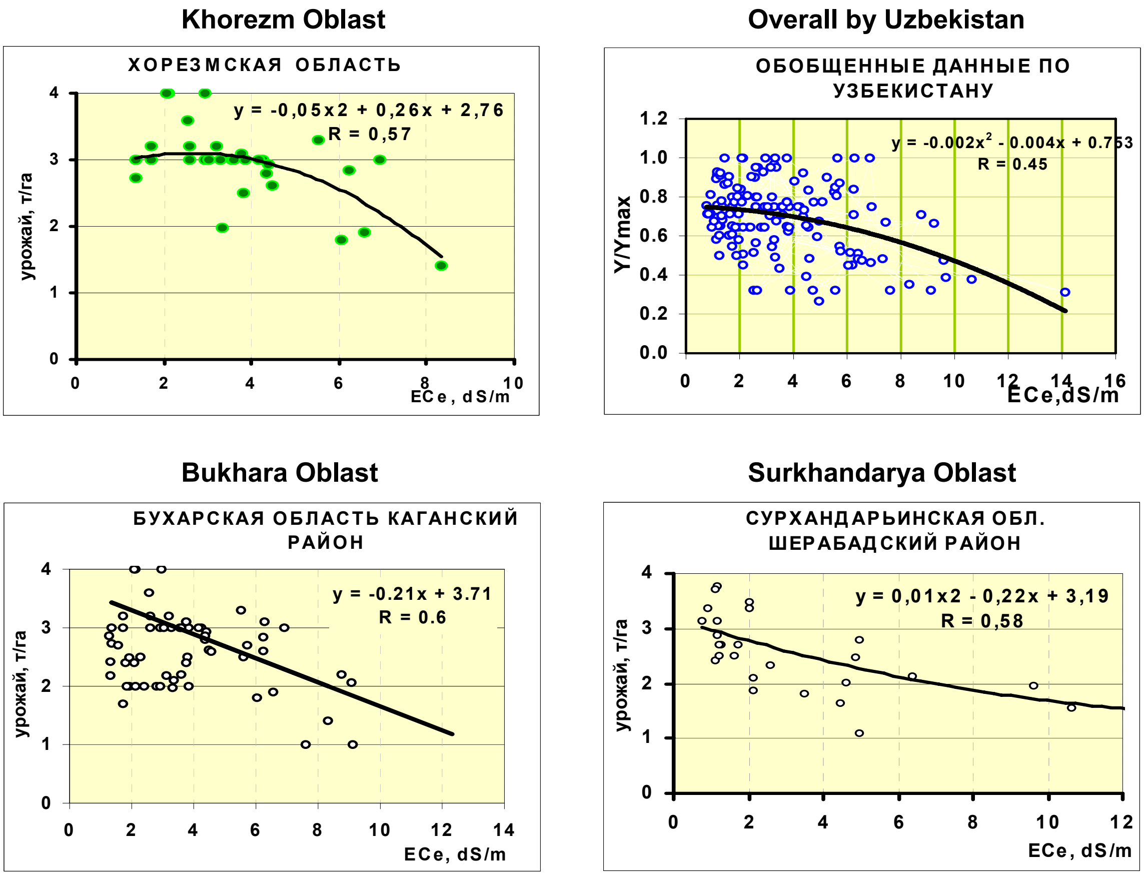
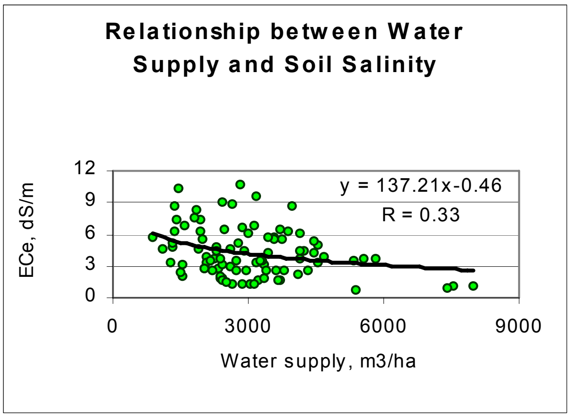
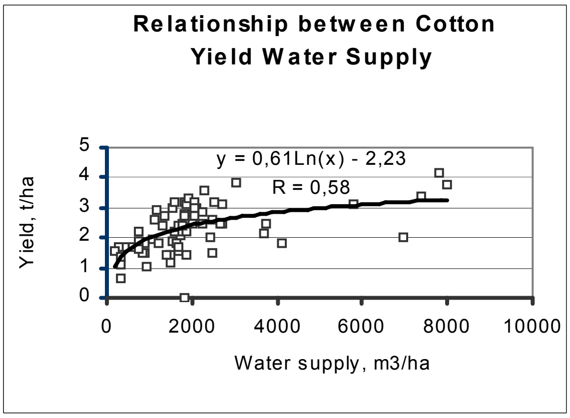


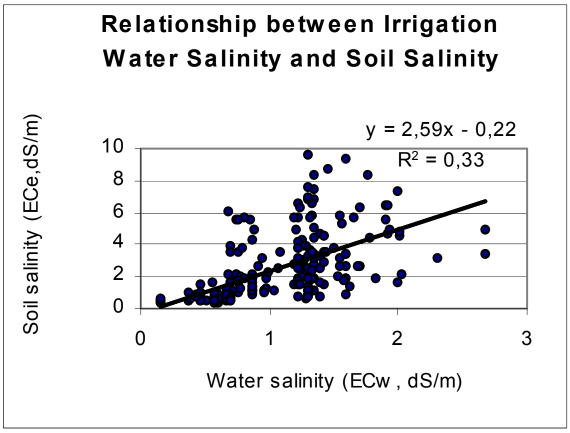
Figure 5.11 Relationships between Some Soil - Water Factors and Yield

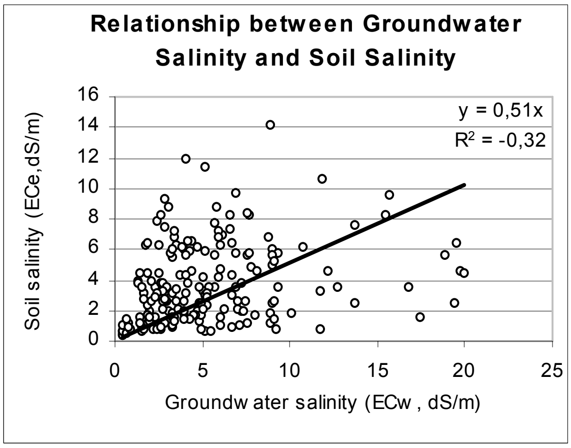
By Data for Uzbekistan





By Data for the Region





5.4 Indices of Soil Fertility

Content of organic carbon (C %), nitrogen in the forms of NO_3 and NH_4, available phosphorus (P) and potassium (K) are indices of soil fertility. Content of available NPK is measured in mg/kg (in international interpretation it means 1/1’000’000 or ppm). According to local classification soil available NPK is evaluated on the basis of total content of nitrogen - N, and content of phosphorus and potassium in the forms of (P_2O_5) and (K_2O). In internationally used methodology soil fertility is evaluated on the basis of content pure P and K. There is a special classification for nitrogen N - NO_3 and N - NH_4. The above classifications and change in available nutrients content during survey period are shown in Tables 5,8; 5.9 5,10; 5,11; 5,12. Humus content by sample fields is not high and in majority cases it is no more than one percent, apart from Kyrgyzstan and Fergana Valley of Uzbekistan (Table 5.8). As a rule, content of humus is not changing too much, but nevertheless its content was increased by 0.1-0.4 percent (weight by weight) during period 1996-1998 (Table 5.8, Figures 5.12, 5.13).

Table 5.8 Change in Humus Content by Sample Farms
(local classification)

Class	Humus content, %	Percentage of sample fields		
		1996	1998	Difference %
No of sample fields		178	157	
Very low	< 0,45	30	13	-17
Low	0,46-0,90	35	48	13
Medium	0,9-1,35	28	20	-8
High	1,35-1,80	7	13	6
Very high	>1,8		6	6

Figure 5.12 Change in Humus Content by Farms of Uzbekistan
(average by 10 sample fields)

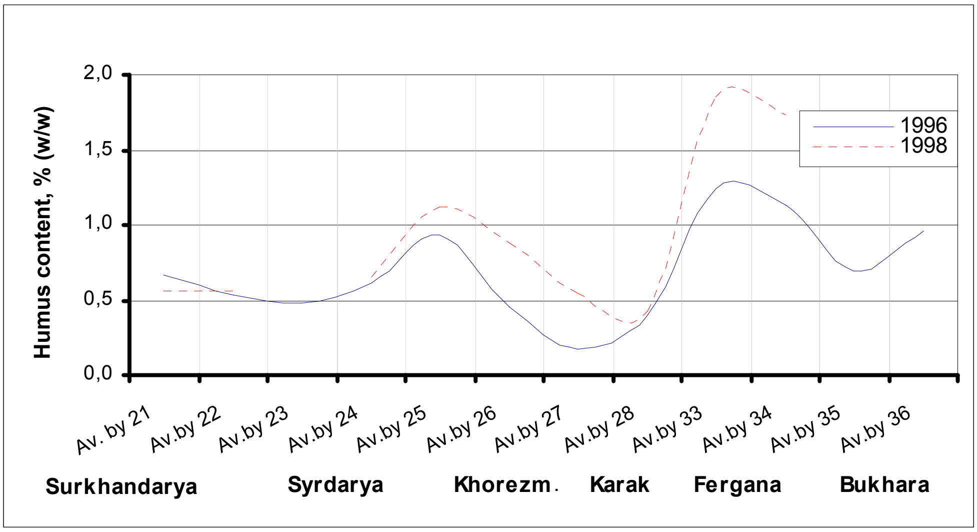
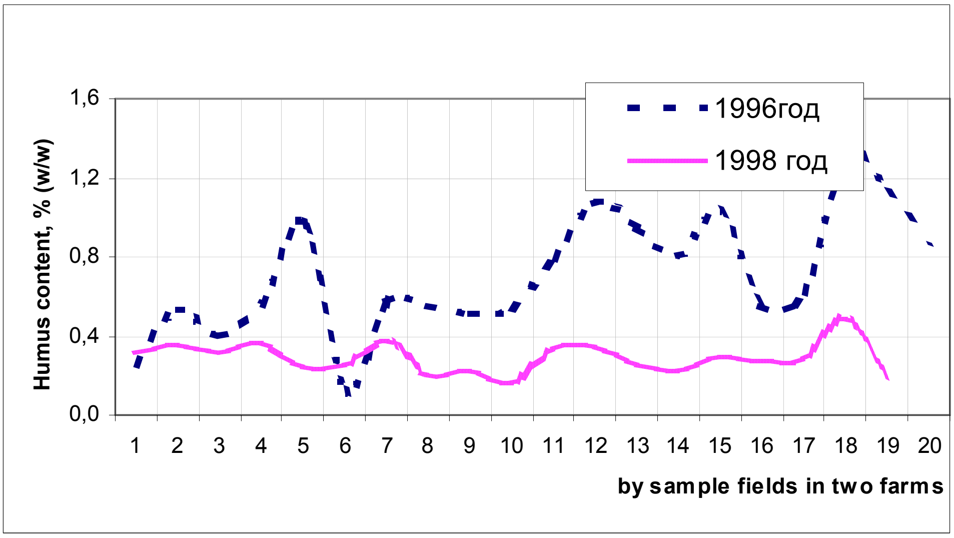


Figure 5.13 Change in Humus Content by Farms of Turkmenistan
(by 20 fields in two twin farms)



In 1996 nitrogen content in majority soil samples was assessed as "very low" (less than 20mg/kg) In 1997 its content was reduced to 6 - 10 mg/kg, in 1998 it was increased and in some farms its content was 20 - 30 mg/kg (Table 5.9 and Figure 5.14).

Table 5.9 Change in Soil Available N, P, K and Humus by Sample Farms
(average by pair of farms)

Years	Farm code											
	1,2	**3,4**	**7,8**	**9,10**	**14**	**17,18**	**21,22**	**23,24**	**25,26**	**27,28**	**33,34**	**35,36**
	N, мг/кг *(ppm)*											
1996	13	12	17	18	18	15	8	14	13	10	16	13
1997	8	9	n.a.	n.a.	n.a.	10	9	8	8	5	n.a.	9
difference in 97 as % of 96	35	27	100	100	100	35	-7	44	37	44	n.a.	31
1998	n.a.	26	21	15	-	20	28	18	13	13	16	27
difference in 98 as % of 96	n.a.	55	20	-19	100	26	71	19	-3	29	0	52
	P, мг/кг *(ppm)*											
1996	21	15	13	13	19	19	8	8	25	7	18	12
1997	9	10	n.a.	n.a.	n.a.	12	8	8	9	12	n.a.	8
difference in 97 as % of 96	56	30	n.a.	n.a.	n.a.	36	0	3	65	-62	n.a.	31
1998	n.a.	12	18	13	n.a.	12	8	15	12	11	13	14
difference in 98 as % of 96	n.a.	17	-39	-3	n.a.	36	-7	-87	51	-42	25	-21
	K, мг/кг *(ppm)*											
1996	115	177	135	141	169	115	142	135	113	100	145	169
1997	106	91	n.a.	n.a.	n.a.	114	93	99	93	126	n.a.	119
difference in 97 as % of 96	8	48	n.a.	n.a.	n.a.	1	35	26	18	-26	n.a.	29
1998	n.a.	221	155	113	n.a.	221	230	240	153	135	188	210
difference in 98 as % of 96	n.a.	20	13	-25	n.a.	48	38	44	26	26	23	19
	C, %											
1996	0.9	0.3	0.7	0.5	0.5	0.3	0.3	0.3	0.4	0.2	n.a.	0.5
1998	n.a.	0.5	0.8	0.4	n.a.	0.4	0.3	0.4	0.6	0.3	1.0	0.7
difference in 98 as % of 96	0.9	-0.2	-0.1	0.0	0.5	-0.1	0.0	-0.1	-0.2	-0.1	1.0	-0.2

Note: n. a – data are not available

Рис.5.14 Change in Soil Available Nitrogen (N) by Sample Farms

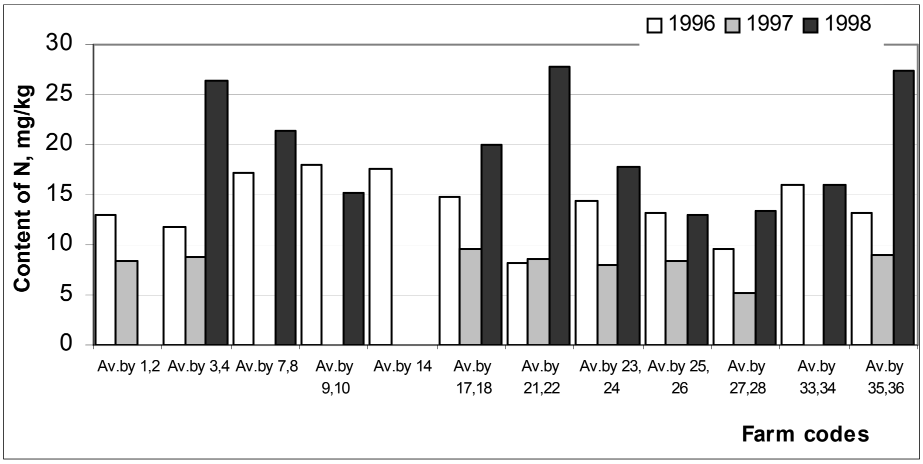


Table 5.10 illustrates, that during 1996 - 1998 number of fields in the category of available nitrogen content "very low" was reduced from 91 percent to 48 percent, and in 1998 25 percent of fields was appeared in the category "medium" available N content and two percent in the category "high"* content.

Table 5.10 Change in Soil Available Nitrogen
(by local classification)

Class	N content mg/kg ppm	As percentage of total sample fields					
		1996	**1997**	**% change 96 - 97**	**1998**	**% change 97 - 98**	**% change 96 - 98**
Total No of fields		137	140		122		
Very low	< 20	91	140	49	48	-92	-43
Low	20 - 30	9		-9	25	25	16
Medium	30 - 50				25	25	25
High	50 - 60				2	2	2
Very high	> 60						

Average content of soil available **phosphorus** is shown in Table 5.9 and Figure 5.15. According to international criteria soils of the region can be mainly placed in the categories "medium" and "high" (Table 5.11). During 1996 - 1997 content of phosphorus was sharply reduced (it is almost halved). In 1998 situation was improved to some extent and 90 percent of fields was in the categories "medium" and "high" available P content.

Local classification of available phosphorus content has five classes and its international version has only three classes. This is more convenient (Table 5.11 A, B). By local classification available phosphorus content in the range 7 –14 mg/kg of P (16 - 32 mg/kg of P_2O_5) is assessed as "low" and by international classification it is "medium". Number of fields with "low" and "very low" available P content *by local and international* classifications was respectively:

- in 1996 - 61 %*) and 15 %**)
- in 1997 - 87 % and 21%
- в 1998 - 70 % and 11 %.

*) – local classification
**) – international classification

Figure 5.15 Change in Soil Available Phosphorus by Sample Farms

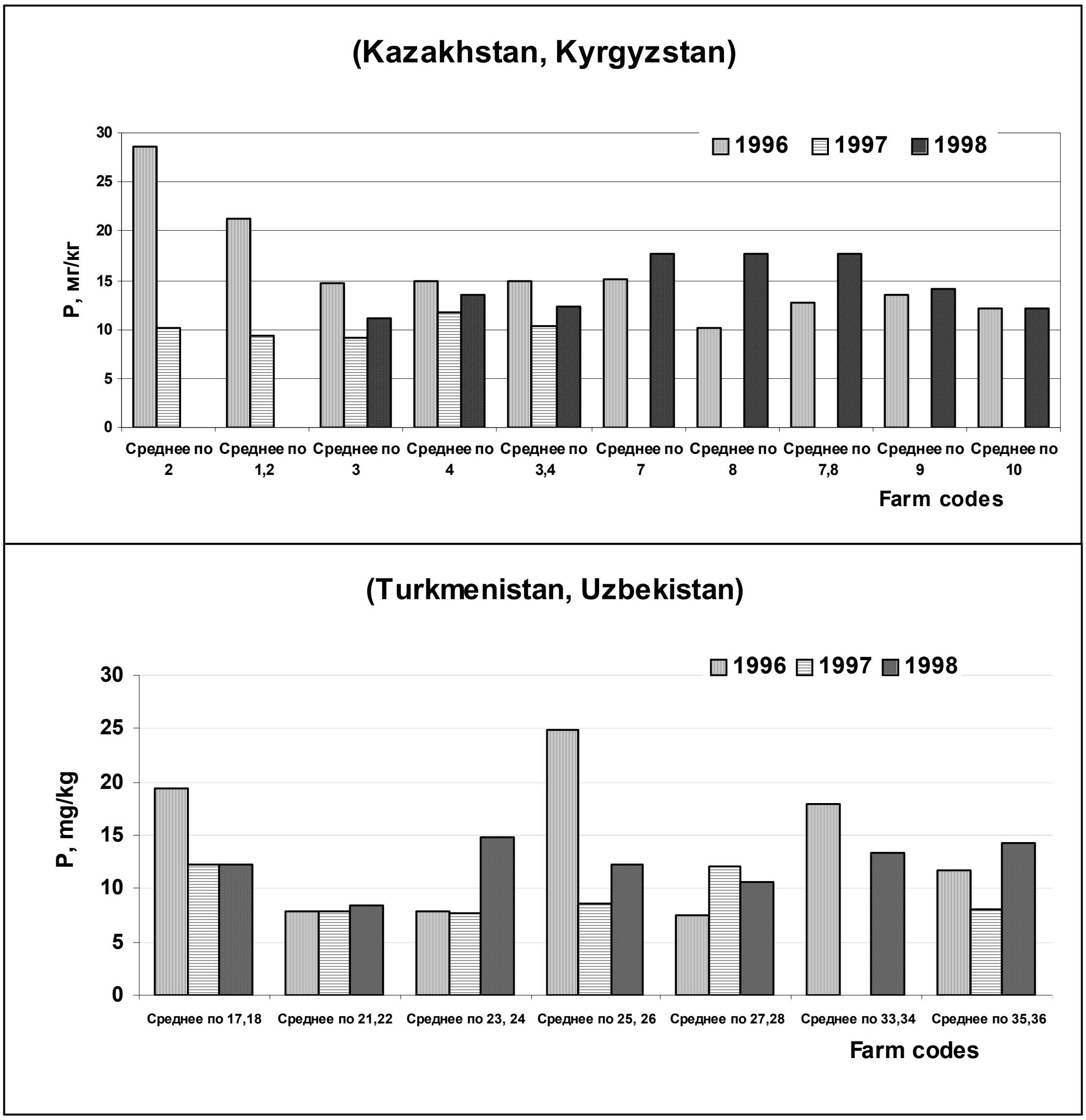


Table 5.11 Change in Soil Available Phosphorus

A) By local classification

Class	Phosphorus content (P_2O_5) mg/kg	As percentage of total sample fields					
		1996	1997	% change 96 - 97	1998	% change 97 - 98	% change 96 - 98
Total No of fields		137	140		119		
Very low	0-15	15	20	5	11	-9	-4
Low	16 - 30	46	67	21	59	-8	13
Medium	31 - 45	19	10	-9	18	8	-1
High	46 - 60	9	3	-6	8	5	-1
Very high	> 60	11	-	-11	4	4	-7

B) By international classification

Class	Phosphorus content (P), mg/kg	As percentage of total sample fields					
		1996	1997	% change 96 - 97	1998	% change 97 - 98	% change 96-98
Total No of fields		137	140		119		
Low	>7	15	21	-6	11	-10	-4
Medium	7 - 14	46	66	-20	59	-7	13
High	<14	39	13	26	30	17	-9

The same situation is with **potassium** (Table 5.12 A, B). By international classification the majority of sample fields was placed in the category “high” and “very high” content (in 1996 – 97 percent, in1997 – 99 percent, in 1998 – 100 percent). But by local classification they were placed in the categories "low" and "very low" content (in 1996 – 76 percent, in 1997 - 99 percent, in 1998 - 44 percent).

This difference in the assessment of nutrients content classes is reflected in the recommended application rates of fertilizers.

By local standards in order to achieve yield 4 t/ha of cotton it is necessary to apply 240 kg/ha of pure nitrogen. During 1970 - 1980 very high fertilizers application rates were used in Central Asian republics and these rates were higher by 20 percent (up to 300 – 400 kg/ha**). [1]

Table 5.12 Change in Soil Available Potassium

A) By local classification

Class	Potassium content (K_2O), mg/kg	As percentage of total sample fields					
		1996	1997	% change 96 - 97	1998	% change 97 - 98	% change 96 - 98
Total No of fields		137	140		119		
Very low	0 - 100	2	6	4	2	-4	0
Low	101 - 200	74	93	19	42	-51	-32
Medium	201 - 300	23	1	-22	30	29	7
High	301 - 400	1			12	12	11
Very high	>400				14	14	14

B) By international classification

Class	Potassium content (K), mg/kg	As percentage of total sample fields					
		1996	1997	% change 96 - 97	1998	% change 98 - 97	% change 96 - 98
Total No of fields		137	140		119		
Low	<40	2					-2
Medium	40 - 80	1	1	0		-1	-1
High	80 - 160	66	98	-32	39	-59	-27
Very high	>160	31	1	30	61	60	30

Data on actual application rate of nutrients with fertilizers are provided in Figure 5.15. Average application rate of nitrogen by sample farms was increased in 1997 as against 1996 from 18 to 60 kg/ha in Kazakhstan, from 35 to 71 kg/ha in Kyrgyzstan, from 20 to 26 kg/ha in Tadjikistan, from 31 to 63 kg/ha in Turkmenistan. In Uzbekistan nitrogen application rate was much more higher. On average in Surkhandarya oblast it was 120, 130 and 144 kg/ha, in Syrdarya oblast - 28, 61 and 58 kg/ha, in Khorezm oblast – 80, 69 and 69 kg/ha and overall average by Uzbekistan it was 55, 67 and 73 kg/ha in 1996, 1997 and 1998 respectively.

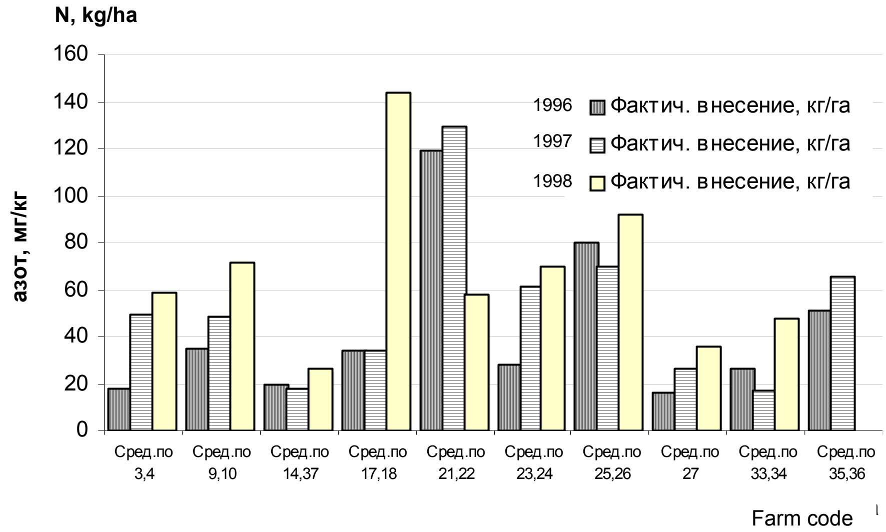
Study of relationship between yield and nitrogen application, accomplished by TACIS expert Henry Back in 1999 (G. Gulyam farm in Syrdarya oblast) showed that cotton yield 1.53 t/ha can be achieved without fertilizer application. In this case plant uses the nitrogen supply, available in soil.

According to the manual "Soil Testing and Plant Analysis" loamy sand, containing up to one percent of humus, can generate 45 kg/ha of nitrogen during vegetation period. Taking this into account Mr H. Back has established requirements of some crops in nitrogen. On the basis of experiments it was found, that cotton nitrogen requirements is 50 kg per each ton of production for

[1] * For the sake of comparability data in Tables 5.8; 5.9; 5.10; 5.11 and 5.12 are given for the fields with three years monitoring.
**Cotton Husbandry Manual, Tashkent, 1981

the condition of Syrdarya oblast. Therefore, it will be necessary to apply only 150 kg/ha of nitrogen in order to achieve yield 3.0 t/ha.

Figure 5.16 Actual Nitrogen Application on Average by Sample Farms



Now in order to use fertilizers more efficiently **it is necessary to review the recommended fertilizer application rates.** Increased application rates, especially on saline soils, are not only economically unjustified, they increase concentration of soil solutions and significant share of fertilizers are leached into groundwater, creating pollution of drainage flow from the fields. The latter causes overgrowing of weeds in drainage collectors and reduction of drainage water discharge.

On the basis of the data of three years WUFMAS monitoring the consumption of nitrogen fertilizer per ton of cotton production was calculated, including the nitrogen, containing in the soil. Average data by the region showed that 65 kg/ha (or 200 kg/ha of ammonium nitrate) of nitrogen will be enough. Taking this rate as basis the actual application rates of nitrogen in the majority of farms in Uzbekistan are very close to 100 percent of requirements (Figure 5.15 and Appendix I 5.8).

Collected data showed, that with application of 50 - 70 percent of required nitrogen application rate the yields were quite high. This data allow recommending to local specialist in agriculture to review the current fertilizer application norms.

In Kazakhstan, Kyrgyzstan, Tadjikistan and Turkmenistan actual phosphorus fertilizer application rates were very small or it was not applied at all, i. e. no more than 7 kg/ha of P or 10 percent of local norms. In Uzbekistan phosphorus fertilizer application rates were higher, but not enough for standard growth of plants. Rates were in the range from 0.4 to 21 kg/ha.

Potassium fertilizer application rates were even lower. There is a common opinion that in Uzbekistan soils have enough potassium. However, assessment based on the project data shows that in order to prevent soil deterioration there is a need to replenish natural potassium supplies in soil by application of potassium fertilizer.