STABILITY OF SOIL AGGREGATES IN ARYS TURKESTAN CANAL COMMAND ZONE

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INTRODUCTION

Aggregate stability is used as an indicator of quality of degraded irrigated soil which is a derivative from soil physical, chemical and biological properties. Dispersion of soil particles is one of the consequences of poor soil properties and poor irrigation practices. Furthermore, dispersion of soil under irrigation is a reason of losses of soil structure, compaction of soil layers, a reduction in soil permeability and increasing soil erosion (McNeal et *al.,*1968; Suarez et al.,1984; Lebron et al.,1994, Elliot et al., 2000, Kjaergaard et al., 2004). On dispersive soils crops invariably have poor above ground growth and weak root system that drastically reduce yields. Farmers often abandon land where the physical properties of soils declined to which a level that the growing of crops is not longer economically viable. Studies have shown that one of the reasons of high level of dispersion under irrigation is changes in chemical properties of soil (Lebron et al., 1994). It was estimated that over 100,000 ha of low-Na+ soil under irrigation in Southern Kazakhstan became highly dispersive due to changes in the soil chemical properties (Vyshpolski *et al.*, 2007).

Arys Turkestan canal command zone is a typical example of an area where these processes are common. Reduction of topsoil organic matter, gypsum and other soluble solids due to inappropriate irrigation of 70000 ha of land has caused degradation of soil physical properties. During irrigation events soil aggregates loose their stability, disperse and form compacted layers during the drying phase. Tillage to a depth of 20 cm causes the formation of massive clods. As a consequence of poor soil properties, vegetative growth of cotton is poor and yield declines to 1.4-1.6 t ha-1 that often results in land abandoment. The same problems are indicated in the middle stream of Syrdarya and Zarafshan river basins, and in Central Tadjikistan (Bodruhina, 1973). Lack of a locally adopted qualitative method of aggregate stability assessment forced retrieval and testing alternative approaches used elsewhere to assess an impact of agricultural practices on soil properties.

Different methods have been proposed to determine soil aggregate stability (Kachinski, 1965; Kemper,1966; Kemper and Rosenau,1986. We followed the method of determining soil aggregate-size distribution and stability after Kemper and Rosenau (1986). Several studies have used capillary-wetted and slaked pretreatments (Elliot, 1986; Cabardella and Elliot, 1993a; Six et. al., 1998; Marquez 2004). The combined use of the capillary-wetted and the slaked pretreatments have been used to determine changes in aggregate-size distributions on soils under irrigation from Arys Turkestan Canal Command (ATC) zone. The objectives of this study were two-fold: (1) to assess aggregate-size stability distribution of low Na+ soil of ATC zone, and; (2) to quantify changes in stability of soil aggregates under long term irrigation with water having poor Ca^{2+}/Mg^{2+} ratio.

The mean weight diameter (MWD) has often been used to indicate the effect of different management practices on soil structure (Angers et al., 1993). Several studies demonstrated that the use of a subsequent slaking following the standard capillary-wetted pretreatment

provides the means for an accurate determination of the amount of stable and unstable macro aggregates (Marquez et al., 1994). The stable aggregates index (SAI) and the stable macro aggregate index (SMAI) were proposed and tested for studying soil stability based on aggregate resistance to slaking. The normalized stability index (NSI) was proposed and tested to characterize soil stability and eliminate confounding effects of pretreatment and antecedent water content and correct effects of differences in sand size distribution among soils (Six et al., 2000). We have used all these parameters to quantify changes in stability of soil aggregates under irrigation in Arys Turkestan Canal command zone.

MATERIALS AND METHODS

Research site

The study was conducted at the Eski Ikan farm located in Arys-Turkestan Canal Command (ATC) zone in Southern Kazakhstan. Mean annual rainfall is at 150 mm that predominantly occur from October to May. The relief is flat, with slopes of 0.1-0.2 degrees. The soil of the area is classified as silt loam, light serozem with low salinity level. Organic matter content in the topsoil is less than 1% and pH value varies from 8.1 to 8.4. The soil is characterised by poor physical properties, in that it is highly dispersive during irrigation and creates a massive structure when dried. Soil bulk density in top 15 cm soil layer is 1.45-1.50 gcm^{-3}, permeability is 0.1-0.3 m day^{-1}. Conventional deep ploughing on these soils results in formation of large impermeable clods. Cotton yields do not exceed 1.4-1.6 t ha^{-1}. Ground water levels are 1.5 m below the surface in spring and decline to 2.5 m in autumn.

Soil sampling

Soil texture was determined by pipette method (Abdullaev et al., 2004). Soil samples used in this study were collected from the area in the fall 2007. Four sites were selected to study soil aggregate stability where soil samples were collected from depth of 0-5 cm (Table 1). On the first site (Ikan A), the soil has clear indications of soil sealing. The soil is highly compacted along the irrigated furrows with deep cracks on the surface. The soil aggregates disperse and loose their stability during irrigation with consequent compaction and decreased permeability when dry. Cotton plants growing on the plot were poor, yield of raw cotton did not exceed 1.5 tha^{-1}. Soil is a silt loam, heavy loam by texture. On the second site (Ikan B), soil did not show evident degradation of soil properties. Stands of cotton plants were significantly better and yield of raw cotton range between 2.2-2.6 t ha^{-1}. Soil is silt loam, moderate loam by texture. On the third site (Ikan C), the soil is highly saline and the farmer has abandoned the plot due to low yields of cotton and accordingly low income from this area. Soil is silt loam, heavy loam by texture. The fourth site was selected from the virgin soil surrounding the irrigated land (Ikan D).

The data presented in Table 1 proves that under irrigation soil (Ikan A and B) had less organic matter content as compared to virgin land on both heavy loam and moderate loam soil. The soil electric conductivity was in range of 0.2-0.4 dS/m against 0.14 dS/m on virgin soil, pH was at 8.1 against 7.7. The irrigated soil had almost two times content of exchangeable [Mg^{2+}] as compared to virgin land.

Table 1 – Selected physical and chemical properties of studied soils collected from the 0-5 cm depth interval (2007)

Location	Sand	Silt	Clay	EC	OM	pH	Exchangeable cations				CEC
							$[Ca^{2+}]$	$[Mg^{2+}]$	$[K^{+}]$	$[Na^{+}]$	
		g kg-1		dS/m	g kg-1			cmolckg-1			cmolckg-1
Ikan A(7)	237(60)	552(78)	212(47)	0.2(0.01)	10.2(.4)	8.1(0.05)	6.5(0.1)	4.0(.1)	0.6(.02)	0.2(0.02)	11.2(0.1)
Ikan B (4)	342(58)	523(64)	135(16)	0.4(0.1)	7.5(0.3)	8.1(0.05)	5.0(0.2)	3.0(.2)	0.3(.03)	0.2(0.05)	8.6(0.4)
Ikan C (1)	158(75)	591(76)	251(20)	1.4(0.3)	19.6(1.6)	7.7(0.04)	5.9(0.1)	4.5(.2)	0.7(0.1)	1.5(0.3)	12.6(0.4)
IKan D	250(119)	526(109)	144(28)	0.14(0.04)	25.5(3.4)	7.6(0.13)	6.3(0.6)	2.2(0.4)	0.6(0.1)	0.1(0.03)	9.19(0.7)

Variations in the cation exchange capacity (CEC) followed the changes in the content of clay particles. Changes in content of Ca were not significant. Different picture was observed on abandoned heavy loam soil (Ikan C).

There was much higher EC and $[Na^+]$ content in the cation exchange capacity of the abandoned soil as compared to virgin and irrigated soil. The content of exchangeable $[Mg^{2+}]$ was at 36% of CEC against 24% under virgin soil. Organic matter content at 0-5 cm soil layer of abandoned soil was at 19.6 g/kg of dry soil, which is close to its value for virgin soil. On abandoned soil pH was at 7.7, which indicates no sodicity issue, while on irrigated heavy loam (Ikan A) or moderate loam (Ikan B) pH was at 8.1. This is even to high level of exchangeable $[Na^+]$ on abandoned soil (12% of CEC) and low level on irrigated soil (2% of CEC).

Characterization of soil aggregates

Aggregate analysis was performed on disturbed soil samples sieved through 8-mm mesh screens under air dry conditions. Two 100-g sub-samples of air-dried soil were used to analyze the aggregate-size stability distribution. Two pretreatments are applied before wet sieving: air drying followed by rapid immersion in water (slaked) and air drying plus capillary rewetting to field capacity plus 5% (capillary-wetted) (Six et al., 1998; Marguez et al., 2004). Both sub-samples were stored overnight in a refrigerator at 4oC before wet sieving. Aggregates were physically separated in sequence in a four aggregate-size fractions: (i) large macro-aggregates > 2000 μm in diameter, (ii) small macro-aggregates between 250 and 2000 μm in diameter, (iii) micro-aggregates between 53-250 μm in diameter, and (iv) the mineral fraction < 53 μm in diameter.

After wet sieving, all the fractions were oven-dried at 70^{o}C, except the large and small macro-aggregates obtained by the capillary-wetted pretreatment. These macro-aggregates were air dried and used for separation of large and small stable aggregates. Sand corrections were performed by subtracting the total sand content of each size fraction from the amount of sample retained on each size fraction. The total sand content of each aggregate-size fraction was determined by weighing the material that was retained on the sieve with a 53 μm screen upon dispersal of the aggregates with sodium hexametaphosphate (5 g L^{-1}). The method is described in detail in Marguez et al. (2004).

Estimation of stable and unstable aggregates

Indices used for evaluating soil aggregate stability were as follows:

(1) Mean weight diameter (MWD) (van Bavel, 1949):

$$MWD = \sum_{i=1}^{n} (x_i y_i) \qquad [1]$$

where x_i is mean diameter of each size-fraction i, and y_i is the proportion of the total sample weight occurring in the size fraction i.

(2) Geometric Mean Diameter (GMD) (Mazurak, 1950):

$$GMD = \exp(\sum_{i=1}^{n}(y_i Ln(x_i)) \Big/ \sum_{i=1}^{n}(y_i)) \qquad [2]$$

(3) Water Stable Aggregates (WSA) (Kemper, 1966; USDA, 1998):

$$WSA(_{\%\ of\ soil>250mm}) = \frac{(weight\ of\ dry\ aggregates)}{(weight\ of\ dry\ soil - sand)} \times 100$$

[3]

4) Normalized Stability Index (NSI) (Six, *et. al.,* 2000):

$$NSI = 1 - \left(\frac{Dl}{Dl_{\max}}\right), \text{ and} \qquad [4]$$

$$DL = \frac{1}{n}\sum_{i=1}^{n}\left[(n+1) - i\right]DLS_i$$

$$DLS_i = \frac{\left\{\left[(P_{io} - S_{io}) - (P_i - S_i)\right] + \left|(P_{io} - S_{io}) - (P_i - S_i)\right|\right\}}{\left[2(P_{io} - S_{io})\right]}$$

$$DL_{\max} = \frac{1}{n}\sum_{i=1}^{n}\left[(n+1) - i\right]DLS_{i\max}$$

$$DLS_{i\max} = \frac{\left[(P_{io} - P_p) + \left|P_{io} - P_p\right|\right]}{\left[2(P_{io} - S_{io})\right]}$$

where DL = soil disruption level; n = number of aggregate size classes; $DL_{\max}$ = the maximum disruption level; DLS_i = disruption level for each size class i; P_{io} = proportion of total sample weight in size class i before disruption (i.e., rewetted); P_i = proportion of total sample weight in size class i after disruption (i.e., slaked); S_i and S_{io} = proportion of sand with size i in aggregates of size i after and before disruption. $DLS_{i\max}$ = maximum disruption; P_p = primary sand particle content with the same size as the aggregates size class after complete disruption of the whole soil. Based on weight losses, *i* = 1 for the smallest size class.

5) Stable Aggregates (SAI) and Stable Macro-aggregates (SMAI) Indices (Marquez et al., 2004):

$$SAI = \frac{(\sum_{j=1}^{n}[(n+1)-j]S_j)}{(\sum_{j=1}^{n}[(n+1)-j]T_j)} \qquad [5]$$

$$SMaI = \frac{(n\sum_{j=1}^{m}[(m+1)-j]S_j)}{(m\sum_{j=1}^{n}[(n+1)-j]T_j)} \qquad [6]$$

where j = 1 for the largest size class, m is the total number of size classes larger than 250 μm; S_j is the amount of stable aggregates in fraction j; T_j is total amount of aggregates in fraction j upon capillary –wetting.

Results and Discussion

Table 2 presents the distribution of soil aggregates among different size fractions as reported after wet sieving. There found significant differences in the distribution of large macro-aggregates (> 2000 μм) under the different soil conditions (Table 2). The amount of stable large macro-aggregates (> 2000 μм) followed the order: virgin moderate loam none saline soil (7.3%) > heavy loam highly saline abandoned soil (6.3%) > moderate loam low saline irrigated soil (3.6%) > heavy loam highly dispersive low saline irrigated soil (1.6%). The consequence for small macro-aggregates was slightly different. The amount of small macro-aggregates in descending order was as follows: moderate loam low saline irrigated soil (8.0%); highly saline abandoned soil (6.9%); virgin soil (5.2%); and heavy loam highly dispersive soil (2.1%). Total amount of stable macro-aggregates (> 250 μм) followed the order: heavy loam highly saline abandoned soil (13.2%) > moderate loam virgin soil (12.5%) > moderate loam irrigated soil under low saline conditions (11.6%) > heavy loam irrigated highly dispersive soil (3.7%).

The results indicate that 33% of large macro-aggregates determined by capillary-wetted pre-treatment were unstable under moderate loam low saline conditions, 34% of large macro-aggregates were unstable under highly saline soil conditions, 38% under virgin moderate loam soil conditions and 43% under heavy loam highly dispersive irrigated soil conditions. Total amount of unstable macro-aggregates (< 250 μм) followed the order: heavy loam highly saline abandoned soil (23.7%) > moderate loam virgin soil (22.5%) > moderate loam irrigated soil under low saline conditions (21.0%) > heavy loam irrigated highly dispersive soil (4.8%). These results confirm that highly dispersive low Na^+ soil contains low amount of stable and unstable macro-aggregates as compared to other studied soil conditions.

The different tendency was observed on behaviors of micro-aggregates. Quantity of micro-aggregates in ascending order was as follows: virgin soil (16.8%); abandoned heavy loam soil (17%); moderate loam irrigated soil (17.1%); and heavy loam irrigated soil (29.7%). High content of micro-aggregates was found on degraded heavy loam highly dispersive irrigated soil. In contrast, heavy loam highly saline abandoned soil (Ikan C) had

more macro-aggregates and less micro-aggregate than irrigated soil. In spite of variations in amount of stable macro- or micro-aggregates in the studied soils, total quantity of aggregates was very close in range of 77.4-80.2%.

Table 2. The aggregate-size stability distribution for three different soil conditions. Values are data from 2007-2008 expressed as percentages of dry weight of soil and on a sand-free basis ±0.1 in each size fraction. TS is the total percentage of stable aggregates and TU is the total percentage of unstable aggregates. TG is the total gain in aggregates from other fractions. T is total percentage of soil aggregates T = TS + TU

Size fraction	Water pretreatments			Aggregate-size stability distribution		
	Slaked	Capillary-wetted	Subsequent-slaked	Stable	Unstable	Gains
μм	%	%	%	%	%	%
Ikan A						
> 2000	1.6(2.5)	2.8(3.6)	0.9(1.4)	1.6(0.3)	1.2(0.8)	
250-2000	3.3(5.2)	5.7(7.7)	2.1(3.3)	2.1(0.3)	3.6(0.5)	1.2(0.5)
53-250	27.4(43.2)	29.7(47.3)		29.7(1.3)		0(0.1)
< 53	42.6(42.6)	41.6(41.4)		41.6(1.4)		1.0(0.8)
Total	74.9(92.7)	79.7(100)		TS= 74.9 T= 79.7	TU= 4.8	TG= 2.2
Ikan B						
> 2000	3.6(5.8)	5.4(6.8)	1.7(2.7)	3.6(1.6)	1.8(0.6)	
250-2000	15.6(25.7)	27.2(33.2)	8.0(13.1)	8.0(0.6)	19.2(1.2)	7.7(0.4)
53-250	22.0(36.3)	17.1(28.3)		17.1(0.1)		4.9(0.7)
< 53	30.0(30)	30.2(30.2)		30.2(1.9)		1.0(1.0)
Total	71.2(97.8)	79.8(98.5)		TS= 58.8 T = 79.8	TU= 21.0	TG= 13.6
Ikan C						
> 2000	6.3(9.5)*	9.4(11.4)	3.1(4.7)	6.3(0.6)**	3.2(1.3)	
250-2000	17.6(26.4)	27.3(31.0)	6.9(10.3)	6.9(1.8)	20.5(3.7)	10.8(3.2)
53-250	22.6(36.2)	17.0(27.3)		17.0(0.1)		5.5(0.5)
< 53	25.2(25.2)	23.6(23.6)		23.6(0.4)		1.6(0.9)
Total	71.6(97.3)	77.4(93.2)		TS= 53.7 T = 77.4	TU= 23.7	TG= 17.9
Ikan D						
> 2000	7.3(12.2)	11.7(14.1)	3.1(5.2)	7.3(2.6)	4.4(2.3)	
250-2000	13.6(22.0)	23.3(27.0)	5.2(8.6)	5.2(1.3)	18.0(4.4)	8.3(3.8)
53-250	21.6(35.0)	16.8(28.3)		16.8(0.4)		4.8(1.5)
< 53	29.4(29.4)	28.5(28.5)		28.5(6.0)		2.5(2.5)
Total	71.9(98.6)	80.2(97.9)		TS= 57.7 T = 80.2	TU= 22.5	TG= 15.6

*Values between parentheses are grams of dry weight of soil without sand correction;
**Values between parentheses are standard deviation of mean

Regression analysis confirm that the amount of large-aggregates that with stood the subsequent-slaking was highly correlated (r^2 = 0.975) with the amount of large macro-aggregates that survived the slaking pretreatment for the studied field sites (Fig.1).

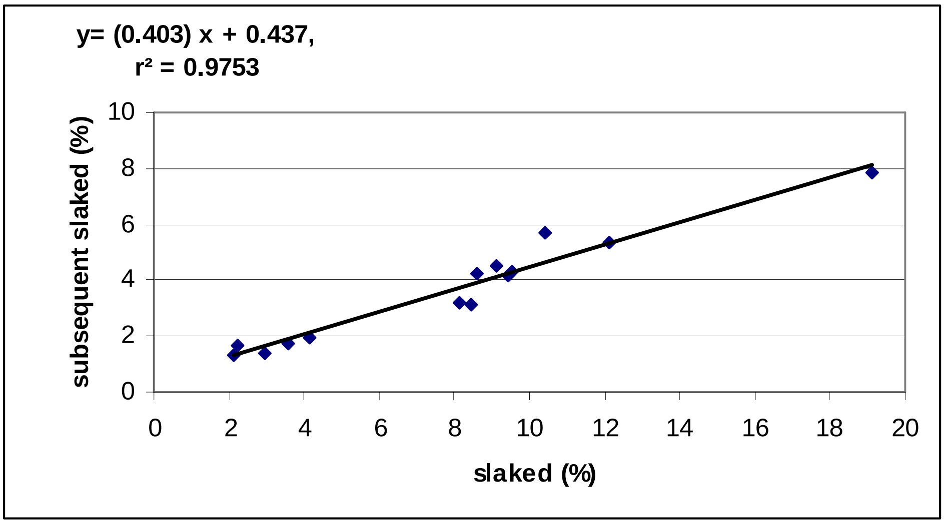


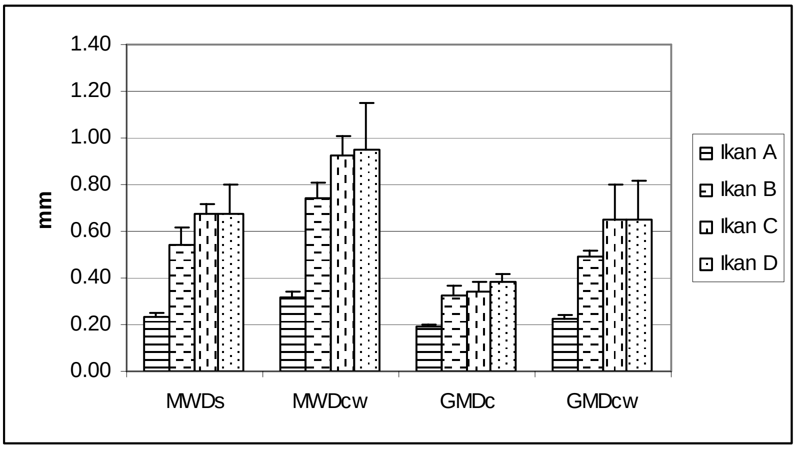
Fig. 1.Relationship between the percentage of large macro-aggregates > 2000 μm quantified by slaked pretreatment and stable large macro-aggregates > 2000 μm quantified by the subsequent –slaking pretreatment. Values are expressed as percentages of soil dry and on a sand free basis.

Figure 2 contains treatment values for different soil aggregate stability indices. Mean weight diameter (MWDs, MWDcw) did show clear trend across the studied soils. A large reduction in MWD was observed upon slaking and capillary wetted pretreatments. The value of MWDs and MWDcw in descending order was as follows: virgin soil > abandoned heavy loam soil under highly saline conditions > moderate loam irrigated > heavy loam irrigated under low saline conditions. The Geometric Mean Diameter (GMDs, GMDcw) and Water Stable Aggregates (WSAs, WSAcw) indices did show similar trends for slaked and capillary wetted pretreatments.

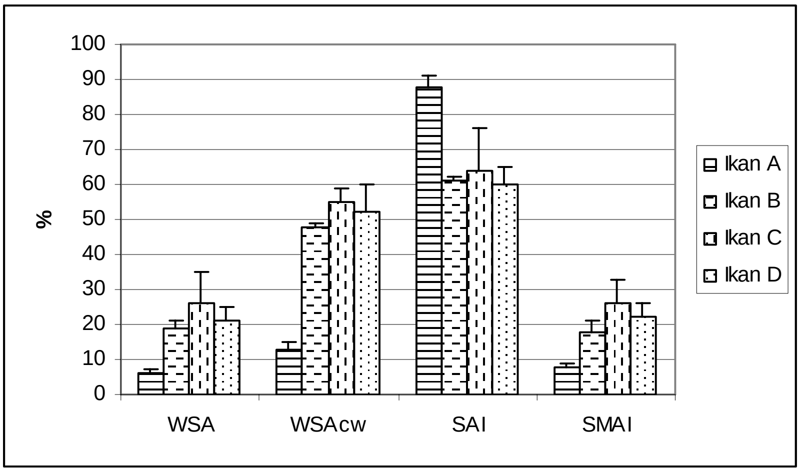
The values of indices for the virgin soil and the abandoned heavy loam soil were very close in all studied cases. All applied indices indicated the same tendency to decline with respect to amount of water stable aggregates at location Ikan C, having highly dispersive gypsum free soils.

The stable aggregate index (SAI) did show significant differences between highly dispersive soil at the site A and other studied soils. The high value of the SAI for degraded soil (Ikan A) indicates that along with reduction of macro-aggregates there is the accumulation of mineral fraction in the degraded soils. However, this index did not show differences for the soil at the other sites including virgin soil.

There was indicated some relation between the environment and the amount of water stable aggregates. Highly dispersive soil had mean weight diameter in range of 202-256 mm, while this value was in range of 484-783 on virgin land, 472-645 on moderate loam irrigated soil and 609-724 on highly saline heavy loam abandoned soil.



a)



b)

Fig. 2 Mean weight diameter of slaked(MWD_s) and capillary-wetted(MWD_{cw}), Geometric water diameter of slaked (GMDs) and capillary-wetted (GMDcw), Water stable aggregates of slaked (WSA_s) and capillary –wetted(WSA_{cw}), Stable aggregate index (SAI) and Stable macroaggregates index(SMAI) of soils under different uses of Arys Turkestan Canal command zone. Values in error bars are standard deviation of means.

Water stable aggregates percentage was less than 10% on highly dispersive soil, from 17-23% on highly saline and from 17-22% on moderate loam soil and from 19-26% on virgin soil. WSA level less than 10% was indication of high dispersibility of the studied soil. The same could be concluded from values of SMAI. Highly dispersive soil had SMAI less than 10%, while for moderate loam soil it was from 15-22, heavy loam highly saline soil from 19-24 and on virgin soil from 16-27%. These values of MWDs, WSAs or SMAI could be taken as indicator of dispersion level of soil.

The stable macro-aggregates index (SMAI) specifies large difference between stable macro-aggregates at the studied soils. Soils subject to high level of dispersion and compaction had lowest values of the SMAI, while moderate loam gypsum free low Na^+ and heavy loam highly saline soil had higher values of the stable macro-aggregate index close to its value for virgin soil. Since the SMAI takes into account the weight loss of macro-

aggregates, which is observed in the studied soils, this index was an appropriate indicator of variations in the soil aggregate stability. The SMAI has reflected changes in the aggregate-size distribution and stability under different dispersion levels of soils of Arys Turkestan Canal command zone. A high correlation between the Water Stable Aggregates using the slaking pretreatment (MWDs) and the stability macro-aggregate index (SMAI) was observed (Fig.3).

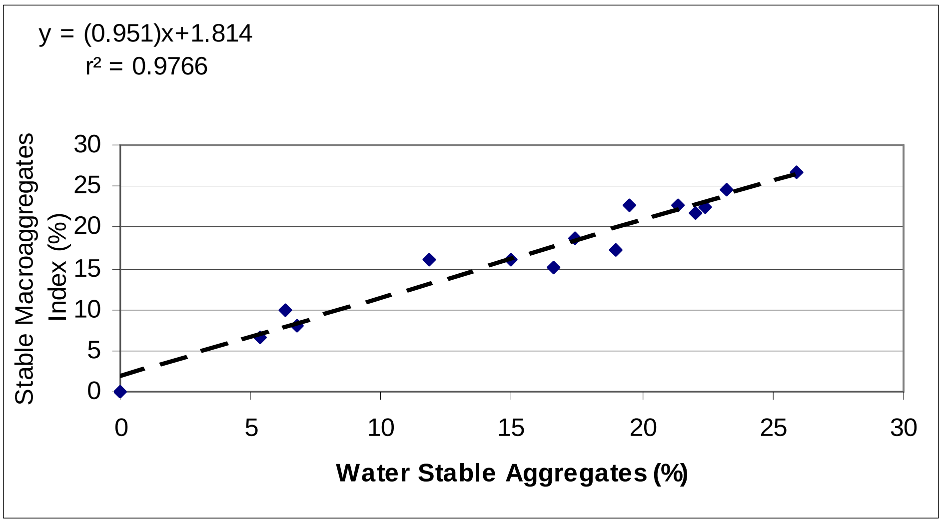


Fig. 3 The Relationship between the Stable Macro-aggregates Index (SMAI) and Water Stable Aggregates (WSAs). Values are expressed as percentages of soil dry and on a sad-free basis

This dependence proves that these two indices are suitable for comparative assessment of stability of soil aggregates, while stable aggregate index clearly shows problematic soils.

We analyzed changes of soil chemical and physical properties as potential factor affecting to dispersion of soil aggregates (Table 3).

Table 3. Water stable aggregates as affected by chemical and physical properties of soil of ATK zone

	Unit	Site D	Site B	Site A	Site C
OM	g/kg	25.5±3.4	7.53±0.48	10.27±0.61	19.63±2.73
P001	%	11.8±2.3	13.5±0.51	21.2±0.2	21.2±1.2
EC	dS/m	0.26±0.03	0.42±0.12	0.22±0.02	1.4±0.55
$CaCO_3$	%	16.9±1.6	23.3±0.2	23.7±0.1	26.5±0.3
$MgCO_3$	%	1.8±0.1	2.9±0.1	2.9±0.1	2.6±0.1
EMGP	-	24±0.4	35±2	38±2	43±4
Gypsum	%	0.19±0.07	0	0	0.56±0.11
pH	-	7.63±0.13	8.13±0.09	8.13±0.09	7.72±0.06
ESP	-	1±0	2±0	2±1	4±1
SAR	-	0.1±0.04	0.45±0.14	0.31±0.05	0.86±0.31
SMAI	%	22±3.9	18±2.9	8.33±1.25	25.67±6.8

The data presented in the Table 3 indicates that under long term irrigation practices organic matter content is decreased from 25.5% (±3.4%) to 7.5% (±0.5) on moderate loam and to 10.3% (±0.6%) on highly dispersive soil. Exchangeable magnesium percentage is increased from 24 (±4) to 35 (±2) on moderate loam and to 38(±2) on highly dispersive soil. The content of $CaCO_3$ in the soil is increased from 16.9%(±1.6%) to 23.3%– 23.7%(0.2%) under irrigation. The same tendency was found for $MgCO_3$ which content is increased from 1.8%(0.1%) to 2.9% (0.1%) under irrigation.

We made assumption that relation between quantity of soil water stable aggregates and soil chemical and physical properties can be describer by none-linear relation:

$$SMAI = \alpha OM + \beta P001 + \theta pH + \varsigma Gypsum + \partial EC + \varepsilon MgCO_3 + \nu CaCO_3 + \kappa ESP + \lambda EMgP + \mu,$$

where $\alpha, \beta, \theta, \varsigma, \partial, \varepsilon, \nu, \kappa, \lambda, \mu$ - design variables.

Values of design variables were found using GAMS optimization package with objective function:

$$MINZ = \sum_{1}^{n} \left[(SMAI_a - SMAI_c)(SMAI_a - SMAI_c) \right]$$

Where $SMAI_a$ - actual value of stable macroaggregates obtained from the soil studies,
$SMAI_c$ - calculated value of stable macroaggregates

The values of the variables were found as follows:

$$\alpha = -0.001;\ \beta = -1.1;\ \theta = .277;\ \varsigma = 0.174;\ \partial = .046;\ \varepsilon = -14.407;$$
$$\nu = -1.995;\ \kappa = 0.669;\ \lambda = 0.886;\ \mu = -1.033$$

The value of 'α' was within the error of estimation of the SMAI.

The dependence obtained indicates that SMAI has inverse dependence with number of particle less 0.001 sizes and content of carbonates of Ca^{2+} and Mg^{2+}. Quantity of stable aggregates had direct dependence with the content of gypsum and soluble ions in the soil. There was no found a confirmation of negative effect of high exchangeable magnesium percentage on aggregate stability.

Sensitivity analysis was carried to find out key factors among studied affecting on soil aggregate stability. The tornado chart was created to show single-factor sensitivity analysis, i.e., for each output value, only one input value is changed from its base case value (Fig. 2).

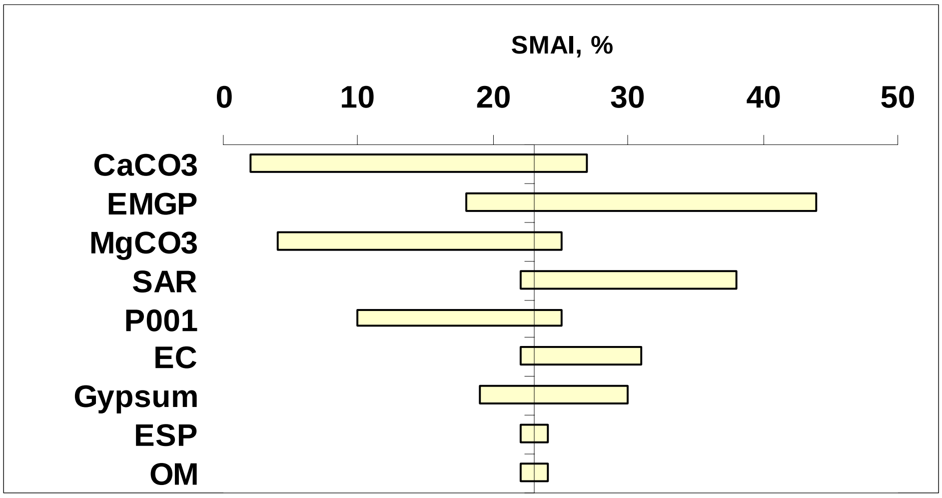


Fig. 4 Tornado chart showing effect of changes in soil chemical properties on SMAI

The tornado chart clearly shows that high content of $CaCO_3$, $MgCO_3$ and particles less than 0.001 mm size are the factors leading to reduction of water stable aggregates. In opposite, high content of soluble ions (EC) and gypsum contribute to increasing water stable aggregates. The data obtained did not prove that exchangeable Mg contributes to high dispersion of soil particles. The data indicates that irrigation of virgin soil of Arys Turkestan canal zone followed by increasing mineral fraction, carbonates of Ca^{2+} and Mg^{2+} in the soil profile and leaching gypsum and soluble ions has led to forming high dispersive properties of the soil of Arys Turkestan Canal zone.

Conclusions

The studies proved that degradation level of irrigated soil of Arys Turkestan Canal Command zone prone to dispersion could be assessed by calculation of Mean Weight Diameter (MWDs), Geometric Mean Diameter (GMDs), Water Stable aggregate (WSAs) or Stable Macro-aggregate (SMAI) induces. All these induce clearly show the trend of reduction of soil stable macroaggregates under irrigation practices existing in Arys Turkestan Canal zone. Stable macroaggregate index (SMAI) was found most suitable to analyze roots of the problem and comparative studies. The value of SMAI less than 10% was found an indication of high dispersibility of soils.

The studies proved increasing the content of particles less than 0.001 mm size, exchangeable [Mg^{2+}] and carbonates of calcium and magnesium in the top layer of highly dispersive soils. In spite of the obtained results did not proving a contribution of exchangeable [Mg^{2+}] on stability of soil aggregates, further studies are required to separate effect of exchangeable [Mg^{2+}] and carbonates of Ca^{2+} and Mg^{2+}.

Poor soil physical properties can be improved by application of alternate furrow irrigation technologies. Farmers of the study area found that alternate furrow irrigation is one of the available methods of irrigation on degraded soils with low water permeability which concentrates a contact of soil with water on alternate furrows and leaves the next free of water. That way, farmers avoid further degradation of soil properties at least on half area of

their irrigated fields. Application of amendments such phosphogypsum can also improve soil properties and yields of agricultural crops (Vyshpolsky, 2007). Another solution is drip irrigation technology using low saline ground water which significantly reduces direct contact zone between water and soil particles. This proposal requires further studies in Arys Turkestan canal command area.

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