THE STATE OF AGGREGATION IN VARIOUS SOIL TYPES IN ISRAEL*

By

S. Ravikovitch and J. Hagin

INTRODUCTION

In the investigation of the soils of Israel, little attention has been directed to the study of the structure and state of aggregation of the various soil types. The definition of these physical properties is of importance in the evaluation of the soils from the genetic, morphological, and agricultural standoints (8, 10, 11, 29). The favorable water and air regimes of the soil, which largely determine the possibilities for crop development, depend on structural properties. Hence, if structure is faulty, moisture and air balance are impaired and yields may be low; this despite the presence in the soil of adequate quantities of available nutrients. The microflora and its activity are likewise affected by soil structure. The relation of size and stability of aggregates to yield levels has previously been established (3, 4, 6, 7, 13, 24, 26).

In soils subject to the dangers of erosion, structural properties largely influence the acceleration or retardation of this destructive process. Soils of unstable structure erode more easily. The improvement and stabilization of aggregation constitute an important means for the prevention of erosion (5, 9, 12, 15, 16, 17). The form of structure and the degree of aggregate stability differ in various soil types. Soils are differentiated into those having distinct and developed structure, undeveloped structure and no structure. The character of the aggregates depends on the presence, amounts, and properties of binding and stabilizing agents, such as mineral and organic colloids, electrolytes, and exchangeable cations; it depends also on the extent of wetting and drying.

Although there are no differences of opinion among investigators as to the great importance of organic matter in the building of stable aggregates, there are disagreements as to the manner in which organic matter acts. Sideri (27, 28) claims that cohesion of soil particles into aggregates is accomplished

* Publication of the Agricultural Research Station, Rehovot. 1957 Series, No. 148-E.

through the physical — chemical bonds which form at the contact areas between the organic and inorganic colloids. Martin (11), on the other hand, holds that the organic matter serves as a medium for the nutrition and activity of soil microorganisms, that the actual binding of soil particles into aggregates is accomplished with the aid of their secretions and through the participation of the cells of microorganisms and fungi mycelia themselves.

In addition to the natural factors which act on the soil and determine the character of the aggregates, the forms of mechanical cultivation, fertilization manuring and liming, crop rotation and irrigation, change the stuctural properties of soils.

The aim of this work is to 1) determine the character of aggregation in the principal soil types of Israel, 2) elucidate the relation between the degree of stability of aggregation and the organic matter, percentage of lime and mechanical composition of the soils, and finally 3) to study the influence of cultivation and irrigation on the changes in aggregation.

METHODS

Size and stability of the aggregates were determined with the aid of the wet sieving method according to Yoder (31); the sieving was done on sieves whose openings were 1.0, 0.5, and 0.25 mm in diameter. The determination of aggregates was carried out in six sample-replicates from each plot. The mechanical composition of the separated aggregates was tested. The mechanical analysis was carried out according to Beam (30) and the aggregation index was calculated according to van Bavel (2); organic matter was analysed according to the method of Scholenberger, as modified by Tiulin (1); the pH was determined electrometrically. Results were evaluated statistically. All data are on the dry matter basis.

The Soils

The character of aggregation was determined for different soil-types taken from non-cultivated locations. In some of the soils, the aggregation was determined in the various horizons of the soil profile; in others, the samples were taken only from the uppermost layer to a depth of 20 cm. in order to determine the influence of soil cultivation on aggregation. For this purpose, samples were gathered from non-cultivated, dry-land farmed and irrigated lands respectively. The soil types tested for aggregation were:

a) terra rossa
b) rendzina
c) loess and loess-like soils
d) brown-red sandy soils
e) grey calcareous soils
f) alluvial soils of Mediterranean red-earths origin.

TABLE 1.

STRUCTURE, AGGREGATE COMPOSITION, MECHANICAL COMPOSITION, ORGANIC MATTER, LIME AND pH IN TERRA ROSSA AND RENDZINA SOILS

Location	Soil type	Depth (cm)	Horizon	Structure	% of aggregates			Aggregation index	Mechanical Composition %				Organic matter %	$CaCO_3$ %	pH
					>1 mm	0.5 — 1.0 mm	0.25— 0.5 mm		Clay <0.002 mm	Silt 0.002 — 0.02 mm	Fine sand 0.02— 0.2 mm	Coarse sand 0.2 — 2.0 mm			
Eilon	Terra Rossa	0—12	A_1	coarse granular	88.8	4.2	2.6	1.45	52.7	12.7	26.2	1.3	7.1	none	7.1
		12—25	A_2	granular	52.3	17.1	12.8	0.97	58.4	22.8	17.9	0.9	3.7	none	6.9
		25—48	B_1	small nutty	21.6	27.4	22.7	0.60	65.4	16.9	17.0	0.7	2.0	none	7.0
		48—60	B_2	prismatic	22.8	27.5	24.4	0.57	65.7	16.3	17.2	0.8	1.5	none	7.1
Ma'aleh-Hahamisha	Terra	0—17	A	granular	83.1	6.3	3.9	1.44	59.2	14.8	25.3	0.7	4.7	1.1	7.6
	Rossa	17—34	B_1	small granular	48.5	21.7	13.8	0.97	64.9	13.5	21.3	0.3	1.7	0.8	7.4
		34—60	B_2	small nutty	25.7	36.4	21.9	0.63	60.0	13.8	22.3	3.9	1.5	7.5	7.6
Dalia	Rendzina	0—20	A_1	granular	69.5	14.6	5.8	1.24	63.6	14.6	15.7	1.1	5.0	2.0	7.2

RESULTS

The Aggregation in Various Soil Types

Terra rossa

From this soil type two profiles were examined, one from Eilon in the Galili mountains, and the other from Ma'aleh-Hahamisha in the Jerusalem mountains. These soils are formed from hard limestone (23). Vegetation plays an important role in their formation (21).

Table 1 presents the results of the analyses of the mechanical composition, organic matter percentage, lime and pH of the soils. The terra rossa soils are clays. Their upper layers are rich in organic matter, which is typical of most soil of this type; they are poor in lime or lacking in it. The structure is granular in the upper layers and nutty, passing into prismatic, in the deeepr layers. Structure of the upper layers, therefore, provides favorable conditions for plant growth. The analysis shows that in the uppermost horizon of the soils, the amount of stable granular aggregates with a diameter greater than 1 mm attains 80—90%; in the B_1-horizon also the percentage is appreciable. In the horizons in which the granular structure is followed by nutty and prismatic structure, there is but a low percentage of aggregates with a diameter greater than 1 mm, and the soil is principally made up of aggregates of 0.5—1.0 mm and even smaller diameters.

The large amount of colloidal organic matter, high percentages of mineral colloids, high exchange capacity, the cation composition in which calcium predominates and sodium is nearly absent, and the specific climatic conditions of alternate wetting and drying, all formed conditions which brought about the creation of stable aggregates of larger diameter. These soils are classed as productive, their favorable structure being one of the factors on which their productivity is based. This good structure also serves as a bulwark against the extreme activities of water erosion which prevail in the mountain regions.

Rendzina soil

This soil belongs to the group of dark rendzinas formed from hard chalk of the Eocene age (32). The soil, according to texture, is a clay; it is rich in organic matter and poor in lime. In the A-horizon a granular structure developed; the percentage of stable aggregates greater than 1 mm attains 70, and the total stable aggregates form 90% (Table 1). Structure in the rendzina soil is, therefore, of high quality, as in the terra rossa soils. The presence of an appreciable percentage of organic matter aggregated the soil particles into a stable granular structure. The soil is endowed with a good water infiltration capacity and is resistant to erosion during the winter. It is classed among the productive soils.

TABLE 2.

STRUCTURE, AGGREGATE COMPOSITION, MECHANICAL COMPOSITION, ORGANIC MATTER, LIME AND pH IN LOESS, LOESS-LIKE AND BROWN-RED SANDY SOILS

Location	Soil type	Depth (cm)	Horizon	Structure	% of aggregates			Aggregation index	Mechanical Composition %				Organic matter %	$CaCO_3$ %	pH
					>1 mm	0.5—1.0 mm	0.25—0.5 mm		Clay <0.002 mm	Silt 0.002—0.02 mm	Fine sand 0.02—0.2 mm	Coarse sand 0.2—2.0 mm			
Sa'ad	Loess	0—17	A	crumby	8.9	4.3	11.9	0.29	18.6	12.1	66.6	2.7	0.72	18.9	8.0
		17—32	A	crumby	10.5	4.8	9.8	0.31	24.0	17.2	56.6	2.2	0.52	22.7	8.0
		32—72	B	crumby-powdery	10.0	6.3	13.5	0.32	26.6	19.6	52.7	1.1	0.29	22.7	8.0
		72—90	B	powdery	4.8	7.0	20.5	0.27	27.4	19.7	51.7	1.2	0.22	23.8	8.1
Dorot	Loess	0—20	A		8.4	8.9	16.5	0.31	33.0	21.5	40.1	5.4	0.46	24.8	8.0
Hatzerim	Loess-like soil	0—20	A		1.8	1.3	5.2	0.13	8.1	13.0	75.3	3.6	0.46	16.9	7.8
Shefayim	Brown-red sandy soil	0—20	A_1	structure-less	0.8	1.5	14.2	0.17	2.5	2.2	89.3	6.3	0.67	none	7.7

Loess and loess-like soils

These are aeolian soils formed under arid and semi-arid climatic conditions. They originate from desert dust material deposited in the northern Negev (20, 23, 32). Fine silica sand constitutes over half of the weight of the loess; the rest is silt and clay. The soil is poor in organic matter (Table 2). Texturally, the soil varies from a loam to a sandy clay loam. Under the arid climatic conditions the soil did not mature, and the horizons in its profile are not clearly defined. The structure is undeveloped; it is crumby-dusty or dusty, and its aggregation is weak. The percentage of aggregation of the larger class (1 mm) is small and lies between 5 and 10. Of the smaller aggregates, those having a diameter of 0.25—0.50 mm. are more abundant. A prolonged drying during the year, low organic matter content, excessive sandiness, and an appreciable percentage of exchangeable sodium — all formed conditions unfavorable for the formation of stable and large aggregates. The soil is subject to the action of wind-erosion since the protective vegetation is destroyed during cultivation; it is also easily carried away by water. During the rainy season and when irrigated by sprinklers, the soil becomes compacted and forms an upper crust which is only slowly permeable to water, thereby aiding erosion.

The soil of Hatzerim is loess-like; it is texturally poorer in the finer fraction than typical loess, and is classed as a sandy-loam. It is very poor in organic matter; lime content is appreciable. The soil is loose and practically structureless. The percentage of aggregates greater than 1 mm is negligible, and the smaller aggregates are also scarce (Table 2). The soil is unstable and subject to erosion.

Brown-red sandy soils

Soils of this type are formed from calcareous sandstone called "kurkar" (19, 23) or directly from shifting sands (22). Texturally, they are sands, sandy loams, loams and sometimes clay loams. The A-horizon is generally sandy. The soils are deficient in organic matter, most of them are lacking in lime, and their exchange capacity is limited. Table 2 presents the mechanical composition of the sandy soil in which the aggregation was determined.

No aggregates greater than 1 mm in diameter formed in the soil in question. To the extent that they are present, the aggregates are of the fine sort.

The deficiency in clay and in organic matter, as against the high content of coarse fractions, prevented the formation of any structure worthy of note in the sandy layers of the brown-red soil. It may, therefore, be considered as practically structureless.

Grey calcareous soils

These soils found in the Jordan and Beisan valleys, were formed primarily through the weathering of the Lisan marls which are prevalent there. This

TABLE 3.

STRUCTURE AND AGGREGATE COMPOSITION, MECHANICAL COMPOSITION, ORGANIC MATTER, LIME AND pH IN GREY CALCAREOUS SOILS

Location	*Depth (cm)*	*Horizon*	*Structure*	*% of aggregates*			*Aggregation index*	*Mechanical Composition %*				*Organic matter %*	$CaCO_3$ %	*pH*
				>1 *mm*	0.5—1.0 *mm*	0.25—0.5 *mm*		*Clay* <0.002 *mm*	*Silt* 0.002—0.02 *mm*	*Fine sand* 0.02—0.2 *mm*	*Coarse sand* 0.2—2.0 *mm*			
Degania	0—17	A_1	medium nutty	34.4	7.0	13.9	0.70	33.9	20.7	33.1	6.3	1.9	41.1	7.9
	17—43	A_2	nutty	15.8	12.3	19.8	0.42	34.5	25.9	34.2	5.4	1.2	43.6	7.9
	43—73	B	crumby	10.1	7.9	18.4	0.31	34.6	30.6	29.1	5.7	0.58	49.6	7.9
	73—90	B	crumby	6.8	6.3	17.5	0.20	40.3	23.0	30.6	6.1	0.43	53.2	7.9
Mesilot	0—15	A_1	medium and large crumby	16.7	13.6	37.6	0.53	42.4	32.4	20.6	4.6	2.8	57.9	7.7
	15—48	A_2	”	27.8	20.8	25.4	0.74	42.3	32.0	19.6	6.1	1.3	54.6	7.9
	48—75	B	small prismatic	13.5	12.0	27.5	0.44	48.9	32.2	15.2	3.7	0.72	44.1	7.9
	75—90	B	prismatic	16.7	19.1	31.4	0.55	51.1	30.6	14.0	4.3	0.60	48.1	8.0
Ashdot Ya’akov	0—20	A_1		24.1	10.4	17.9	0.56	49.3	30.7	18.2	1.8	1.5	37.2	7.9

weathered material received admixtures of calcareous erosional material from the adjacent mountains. The soils are deep, their profiles generally undeveloped and their horizons not marked. They are rich in lime, and contain a relatively appreciable percentage of organic matter. Texturally they are classified as clay-loams and clays (Table 3). The structure is medium nutty or crumby; in the heavier soils it becomes prismatic in the B-horizon. The quantity of aggregates greater than 1 mm is but medium in the A_1—A_2 horizons; it decreases with depth. The aggregates which form the nut and crumb structure of these soils are largely of small size. The appreciable percentage of lime, particulary in the clay fraction, endows the soils with favorable physical properties from the standpoint of water infiltration and aeration (18). The soils are fairly stable toward the action of erosion. Their cultivation with various mechanical implements is relatively easy.

Alluvial soils

Table 4 presents data on the mechanical composition, organic matter and lime content of a group of alluvial soils and of a colluvial soil. They developed from the alluvium of Mediterranean red-earths, formed principally from limestone formations; in one case there is an admixture of alluvial material of basalt origin. The alluvium of Mediterranean red-earths may in some cases have received additions of rendzina alluvium or aeolian deposits.

All of the alluvial soils, except that to which aeolian deposits were added, are clay soils, and heavy throughout their profile. The soil which contains aeolian material is a sandy clay loam in the A-horizon and a sandy clay in the B-horizon. All of the soils contain lime, in various amounts. Except for the terra rossa colluvium, they are relatively poor in organic matter. Their structure is granular or nutty in the upper horizons, becoming crumb or prismatic with depth. All of the heavy alluvial soils contain but limited percentages of aggregates greater than 1 mm, although the percentages of smaller stable aggregates are high. The fine aggregates which are present in appreciable percentages impair the physical properties of the soils. The soils in question are noted for their slow rate of water infiltration and impaired aeration during irrigation. The terra rossa colluvium differs in these respects. This soil is rich in organic matter and contains appreciable percentages of aggregates greater than 1 mm, particularly in the A-horizon. With depth, the percentages of smaller aggregates increase, as in the heavy alluvial soils. The least developed aggregation occurs in the lighter alluvial soil to which aeolian desert dust was added; the fine aggregates constitute appreciable percentages in this soil.

TABLE 4.

STRUCTURE AND AGGREGATE COMPOSITION, MECHANICAL COMPOSITION, ORGANIC MATTER, LIME AND pH IN ALLUVIAL SOILS

Location	Soil type	Depth (cm)	Horizon	Structure	% of aggregates > 1.0 mm	% of aggregates 0.5—1.0 mm	% of aggregates 0.25—0.5 mm	Aggregation index	Mechanical composition % Clay <0.002 mm	Mechanical composition % Silt 0.002—0.02 mm	Mechanical composition % Fine sand 0.02—0.2 mm	Mechanical composition % Coarse sand 0.2—2.0 mm	Organic matter %	$CaCO_3$ %	pH
Halsa	Colluvium of terra rossa	0—17	A_1	Coarse and medium granular	41.5			0.84	67.2	19.2	12.6	1.0	3.1	1.7	7.8
		17—34	A_2	,,	35.8			0.75	67.5	20.4	10.9	1.2	2.3	1.5	7.8
		34—71	B	small crumb	17.1			0.54	66.9	19.6	12.4	1.1	1.6	4.8	7.9
		71—90	B	,,	7.6			0.37	67.6	19.3	11.8	1.3	1.2	2.7	7.9
Merhavia	Developed from alluvium of Mediterranean red earth (of limestone and basalt origin)	0—22	A	coarse and medium granular	13.3			0.34	61.9	18.9	18.2	1.0	1.4	14.8	7.8
		22—38	A	granular and flaky prismatic	15.9			0.46	62.5	20.6	16.1	0.8	1.1	16.0	7.7
		38—78	B	,,	11.8			0.41	63.1	20.7	15.4	0.8	0.97	15.0	7.8
		78—90	B	,,	11.6			0.48	63.1	20.3	15.3	1.3	0.88	16.4	7.9
Ramat David	Developed from Mediterranean red earth (of limestone origin and rendzina)	0—15	A_1	med. granular	25.8			0.69	65.7	18.9	14.0	1.4	1.1	5.9	7.7
		15—37	A_2	coarse granular	12.0			0.50	66.2	18.3	14.3	1.2	0.93	6.4	7.6
		37—70	B	small and med. granular	10.4			0.47	66.9	18.5	13.6	1.0	0.74	5.8	7.7
		70—90	B	,,	18.8			0.68	67.4	17.7	13.4	1.5	0.65	6.9	7.8
Nahalal	As above	0—20	A		16.8			0.53	65.4	19.9	13.5	1.2	1.7	9.6	7.8
Breir	Developed from alluvium of Mediterranean red earth and aeolian deposition	0—21	A	coarse and medium nutty	10.3			0.30	24.5	14.2	56.6	4.7	0.81	13.4	7.7
		21—55	A	,,	16.4			0.40	27.1	15.4	55.1	2.4	0.66	14.8	8.0
		55—65	B_1	coarse crumby	15.2			0.46	38.0	19.0	41.0	2.0	0.60	17.8	7.8
		65—90	B_2	prismatic	13.6			0.41	36.4	18.0	43.1	2.5	0.49	16.7	7.9

DISCUSSION AND CONCLUSIONS

From the standpoint of their aggregation, the different soil types which were examined can be divided into 4 groups. The division was aided by the aggregation index values, calculated according to the formulae of van Bavel (2). This aggregation index reflects the aggregation in summarized form.

a) Soils of highly developed, stable aggregation (>0.5 mm). They are especially notable for the very high percentage of aggregates greater than 1 mm in diameter in their uppermost horizon, and for a high percentage in the underlying horizon. To this group belong the terra rossas and rendzinas (of hard chalk origin). The total amount of stable aggregates greater than 0.5 mm. in diameter in the upper horizon of uncultivated soils is close to 90%; in the next horizon it is about 70%.

b) Soils of medium aggregation (> 0.5 mm) in the A_1 and A_2 horizons ranging from 30—50%, but limited in aggregates greater than 1 mm in diameter. The terra-rossa colluvium, the alluvial soils, and the grey calcareous soils — are endowed with such an aggregation.

c) Soils of but limited stable aggregation (> 0.5 mm) and deficient in aggregates greater than 1 mm in diameter. In the loess soils the content of aggregates smaller than 0.5 mm is approximately 15%.

d) Soils with negligible stable aggregation (> 0.5 mm), practically lacking in aggregation of this size. The brown-red sandy soils and loess-like soils come under this category.

Organic matter played a foremost part in the formation of the larger aggregates (> 1.0 mm); the relation between the organic matter and such aggregates is notable in the terra rossa and rendzina soils, especially in the upper horizons where organic matter accumulated. In soils of other types, in which the organic matter content was lower, the percentages of aggregates larger than 1 mm were correspondingly lower. The formation of stable aggregates of the smaller sort (0.5 — 1.0) also depends on the organic matter. The relation of the aggregation (in the A-horizon), expressed as the aggregation index and the organic matter percentage in the soil, can be seen in Figure 1.

A general dependence of aggregation on soil texture is evident. The coefficient of correlation, which expresses the relation of aggregates larger than 1 mm to the clay content, is + 0.60, and is significant at the 1% level.

The high lime content of the soils did not impair the formation of stable aggregates larger than 0.5 mm in diameter. The total aggregation in the plow-layer of the highly calcareous soils (40—60% $CaCO_3$) is similar to that of the alluvial soils which contain only 2—15% lime.

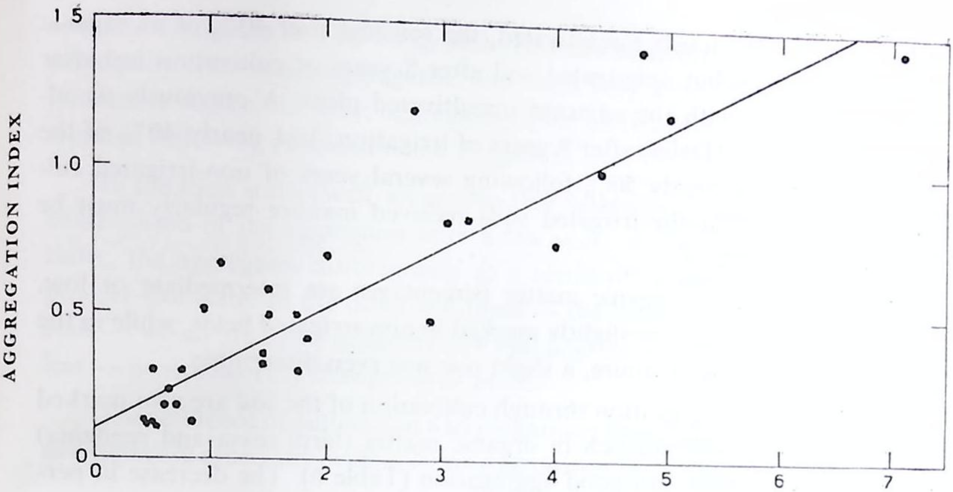

Fig. 1. The relation between aggregation index and percentage of organic matter in the soil.

THE INFLUENCE OF CULTIVATION ON SOIL AGGREGATION

The influence of irrigation and cultivation on aggregation was determined in the plow layer of uncultivated, dry-farmed and irrigated lands. On each site soils of the specific type were selected; the plots, though variously cultivated, were situated as close as possible to each other. The mechanical composition, percentage of lime and pH were similar in the uncultivated and cultivated fields. Aggregation was examined in terra rossa, rendzina, alluvial, grey calcareous and loess and loess-like soils. The data pertaining to the composition of the uncultivated soils are presented in Tables 1—4. Table 5 gives

TABLE 5.

CHANGES IN ORGANIC MATTER CONTENT OF SOILS UNDER CULTIVATION

Location	*Soil type*	*Percent organic matter*			*Years irrigated*
		Uncultivated	*Dry-farmed*	*Irrigated*	
Eilon	Terra rossa	7.1	5.9	4.0	5
Dalia	Rendzina	5.0	2.7	3.2	8
Ashdot Ya'akov	Grey calcareous soil	1.5	1.4	1.7	10
Nahalal	Alluvial soil	1.7	1.5	1.8	10
Dorot	Loess	0.46	0.61	0.61	8
Shefayim	Brown-red sandy soil	0.67	0.46	0.67	5
Hatzerim	Loess-like soil	0.46	0.41	0.46	2

the organic matter percentages in cultivated and cultivated soils. The data show that in soils rich in organic matter, such as terra rossa and rendzina, the organic matter content decreased markedly in the wake of cultivation and irrigation. After only 5 years of cultivation and irrigation of terra rossa soil

(Eilon) that was previously uncultivated, the soil lost over 40% of its organic matter; a cultivated but unirrigated soil after 8 years of cultivation lost over 30%, as compared with the adjacent uncultivated plots. A previously uncultivated rendzina soil (Dalia) after 8 years of irrigation, lost nearly 40% of the organic matter, and nearly 50% following several years of non-irrigated cultivation. The fact that the irrigated soils received manure regularly must be taken into consideration.

In soils which the organic matter percentages are intermediate or low, the organic matter losses are slightly marked in non-irrigated fields, while in the irrigated fields receiving manure, a slight rise was even discernible.

The changes in aggregation through cultivation of the soil are also marked most in the soils which are rich in organic matter (terra rossa and rendzina) and generally endowed with good aggregation (Table 6). The decrease in percentage of aggregates larger than 1 mm in diameter in terra rossa was large, amounting to 40% in a cultivated non-irrigated field, and 60% in the irrigated soil. In rendzina, this decrease in aggregates was not found for the cultivated non-irrigated field, but amounted to 40% in the irrigated field. In the course of their disintegration, the aggregates of the larger diameter (> 1.0 mm) were broken down into aggregates of smaller size (0.5—1.0 mm, or even 0.25—0.5 mm). In some cases, cultivation and irrigation actually disintegrated some of the larger agggregates into units smaller than 0.25 mm. A limited number of years of irrigation sufficed to disrupt a good part of the large stable aggregates and produce a dust-like condition of the soil.

TABLE 6.

THE CHANGES IN AGGREGATE COMPOSITION OF SOILS UNDER CULTIVATION

Location	*Type*	*Uncultivated*				*Dry farmed*				*Irrigated*			
		% aggregates			*Aggregation index*	*% aggregates*			*Aggregation index*	*% aggregates*			*Aggregation index*
		>1.0 mm	0.5-1.0 mm	0.25-0.5 mm		>1.0 mm	0.5-1.0 mm	0.25-0.5 mm		>1.0 mm	0.5-1.0 mm	0.25-0.5 mm	
Eilon	Terra rossa	88.8	4.2	2.6	1.45	53.8	16.1	16.7	1.03	34.8	19.8	21.9	0.75
Dalia	Rendzina	69.5	14.6	5.8	1.24	69.2	15.2	6.6	1.24	39.4	22.9	18.8	0.85
Ashdot Ya'akov	Grey calcareous soil	24.1	10.4	17.9	0.58	12.5	7.8	16.7	0.37	5.2	9.3	24.7	0.29
Nahalal	Alluvial soil	16.8	17.3	23.1	0.53	12.0	22.2	29.4	0.49	8.8	17.3	36.7	0.42
Dorot	Loess	8.4	8.9	16.5	0.31	8.7	2.9	7.9	0.23	1.9	2.0	16.6	0.18
Shefayim	Brown-red sandy soil	0.8	1.5	14.2	0.17	0.6	1.4	10.4	0.14	0.6	1.4	10.4	0.14
Hatzerim	Loess-like soil	1.8	1.3	5.2	0.13	2.3	1.3	4.3	0.13	1.9	1.5	5.9	0.13

Similar changes were also evident in the grey calcareous and alluvial soils. The percentage of aggregates larger than 1 mm in diameter, which is naturally relatively low in these soils, decreased in a cultivated non-irrigated soil by 50%, and in an irrigated soil by 80%, after 10 years of irrigation. They were turned principally into small aggregates, and even into a powdery condition. To a noticeable degree, the large aggregates of the alluvial soil of Nahalal also disintegrated following cultivation and irrigation.

In the loess soil as well, an appreciable deleterious change took place in the composition of the aggregates after a few years of irrigation. In this soil especially, the aggregates disintegrated as a result of irrigation and turned into a powder-like state. In the other soil types — the loess-like and brown-red sandy soils — which are light, generally not well aggregated and practically structureless — no noteworthy changes took place.

The influence of cultivation and irrigation on the aggregation in the various soil types are especially evident in the aggregation index presented in Figure 2.

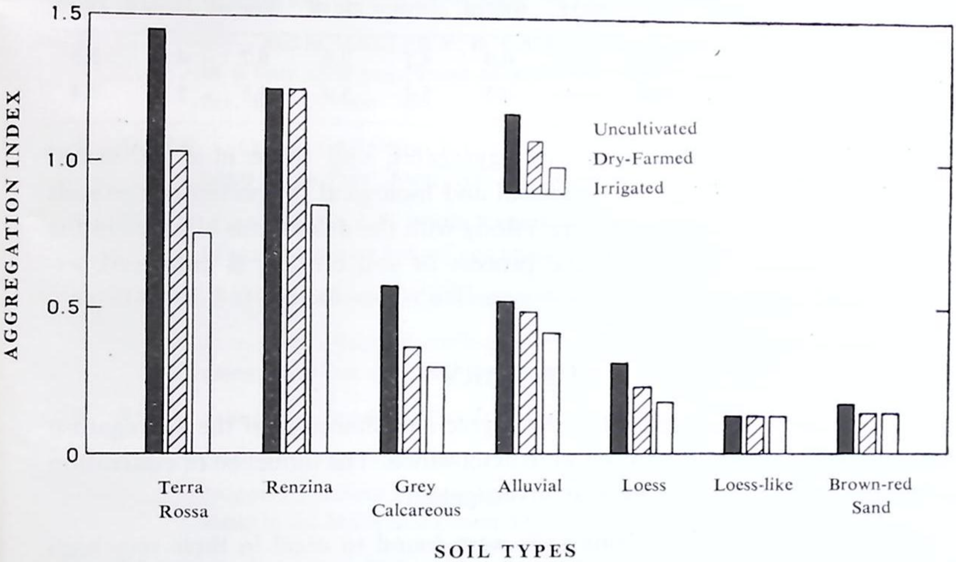

Fig. 2. The influence of cultivation and irrigation on aggregation in the various soil types.

In addition to mechanical cultivation of the soil with various implements, destruction of the favorable granular structure resulted principally from decomposition of the organic matter. The organic matter which accumulates in a non-cultivated soil from the natural vegetation, decomposes progressively as the soil is cultivated following the eradiction of this vegetation. The aggregates of the various diameters begin to lose their organic matter, though themselves remaining stable; this continues it seems, up to a certain limit, after which the aggregates begin to disintegrate intensively. The appreciable differences in the organic matter contents in aggregates of nearly equal diameter size in cultivated, dryfarmed and irrigated fields of terra rossa and rendzina soils, can be seen in Table 7. The greatest loss in organic matter occurs in the aggregates of irrigated soils where the aggregates apparently reached the stage where their binding is already weakened. The process of the disintegration of the larger aggregates into smaller ones is most accelerated in the irrigated fields. In such lands the sodium of the irrigation water, which is absorbed by the mineral and organic colloids, may also aid in their removal from the aggregates during the rains, by disrupting the stability of the aggregates.

TABLE 7.

THE INFLUENCE OF CULTIVATION AND IRRIGATION ON THE CHANGES IN ORGANIC MATTER CONTENT IN THE AGGREGATES

Loca-tion	*Soil type*	> 1.0 *mm*			0.5 — 1.0 *mm*			0.25 — 0.5 *mm*		
		uncul-tivated	*dry-farmed*	*irri-gated*	*uncul-tivated*	*dry-farmed*	*irri-gated*	*uncul-tivated*	*dry-farmed*	*irri-gated*
Eilon	Terra rossa	5.9	4.8	3.7	6.0	4.1	3.6	6.2	4.3	3.5
Dalia	Rendzina	4.8	3.6	3.4	4.5	3.4	3.4	4.8	3.3	3.4

The appearance of the very fine aggregates, and those in a pulverized condition, impairs the physical, chemical and biological properties of the soils and lowers their level of productivity. Along with the deleterious changes in the infiltration capacity of the soil, the process of soil erosion is enhanced, especially in the mountain region.

SUMMARY

The structure was defined and the degree and character of the aggregation in the principal soil types of Israel were determined. The influence of cultivation on the aggregation of the soils was investigated.

The terra rossa and rendzina soils were found to excel in their very high degree of stable aggregation (> 0.5 mm).

An intermediate degree of stable aggregation (> 0.5 mm) typifies the colluvium of terra rossa, the alluvial soils of Mediterranean red-earths origin, and the grey calcareous soils.

The loessial soils posses a limited degree of stable aggregation (> 0.5 mm).

Loess-like and brown-red sandy soils have but negligible aggregation.

A correlation is discernible in the upper horizons between the amount of organic matter and the degree of aggregation, especially with respect to the aggregates larger than 1 mm in diameter.

Stable and well developed aggregation also forms in the soil in the presence of high percentages of lime (40—60 % $CaCO_3$).

The cultivation of previously uncultivated soil for a period of 5—10 years brought in its wake losses in organic matter mainly in terra rossa and rendzina soils; as a result of this, far reaching changes took place in the aggregation. Along with the cultivation and irrigation, a large percentage of aggregates larger than 1 mm in diameter disintegrated into fine aggregates. In addition, a good part of the aggregates were pulverized into powder-like form (0.25 mm). The quality of aggregation was most impaired under irrigation.

REFERENCES

1. ANONYMOUS (1941) Metody agrokhimicheskikh i agrofizicheskikh isledovanii v polivnikh khlopkovikh raionakh Izd. Narkomzem. SSSR.

2. van BAVEL, C. H. M. (1949) Mean weight diameter of soil aggregates as a statistical index of aggregation. Proc. Amer. Soil Sci. Soc. 14: 20—23.

3. ———— and SCHALLER F. W. (1951) Soil aggregation, organic matter and yields in a long time experiment as affected by crop management. Proc. Amer. Soil Sci. Soc. 15: 399—404.

4. BAVER, L. D. and FARNSWORTH, R. B. (1941) Soil structure effects in the growth of sugar beets. Proc. Amer. Soil Sci. Soc. 5: 45—48.

5. ELSON, J. and LUTZ, J. F. (1940) Factors affecting aggregation of Cecil soils and effect of aggregation on run-off and erosion. Soil Sci. 50: 265—276.

6. HAGIN, J. (1952) Influence of soil aggregation on plant growth. Soil Sci. 74: 471—478.

7. ———— (1955) Rates of nitrification in natural and conditioner formed soil aggregates of various sizes. Bull. Res. Counc. Israel 5: 98—104.

8. JOFFE, J. S. (1949) Pedology, Pedology Pub. New-Brunswick, N. J.

9. JOHNSTON, J. R., BROWNING, G. M. and RUSSELL, M. B., (1942) The effect of cropping practices on aggregation, organic matter content and loss of soil and water in the Marshal silt loam. Proc. Amer. Soil Sci. Soc. 7: 105—107.

10. KRISHNA, P. G. and PERUMAL, S. (1948) Structure in black cotton soils of the Nizamsagar project area, Hyderabad State, India, Soil Sci. 66: 29—38.

11. MARTIN, J. P. (1942) The effect of composts and compost materials upon the aggregation of the silt and clay particles of Collington sandy loam. Proc. Amer. Soil Sci. Soc. Vol. 7.: 218—222.

12. MIDDLETON, H. E. (1930) Properties of soils which influence soil erosion U. S. D. A. Tech. Bull. 178 pp. 15.

13. MONSELISE, S. P. and HAGIN, J. (1955) Influence of soil aggregation on the rooting of carnation cuttings. Plant and Soil 6: 245—250.

14. NIKIFOROFF, C. C. (1941) Morphological classification of soil stucture. Soil Sci. 52: 193—212

15. PEELE, T. C. (1937) The relation of certain physical characteristics to the erodibility of soils. Proc. Amer. Soil. Sci. Soc. 2: 97—100.

16. ——————— and BEALE, O. W. (1941) Effect on runoff and erosion of improved aggregation resulting from the stimulation of microbial activity. Proc. Amer. Soil. Sci. Soc. 6: 176—182.

17. ———————, LAHTAM, E. E. and BEALE, O.W. (1954) Relation of the physical properties of different soil types to erodibility. S. Carolina Agr. Exp. Sta. Bull. 357.

18. RAVIKOVITCH, S. (1946) The saline soils of the Lower Jordan Valley and their reclamation. Agr. Res. Sta. Rehovot. Bull. 39.

19. ——————— (1950) The brown red sandy soils of the Sharon and the Shephela. Agr. Res. Sta. Rehovot. Bull. 55.

20. ——————— (1952) The aeolian soils of the Northern Negev. Proc. Symposium on Desert Research, Jerusalem. Pp 30.

21. ——————— and PINES, F. (1955) The mountain soils of Israel. The Forest, No. 4 59—63

22. ——————— and RAMATI, B. (1957) The agricultural utilization of shifting sands and the effects of cropping on them. Agr. Res. Sta. Rehovot, Ktavim Vol. 7. No. 2—3.

23. REIFENBERG, A. (1947) The Soils of Palestine. Thomas Murby & Co. London.

24. RICHARDS, S. J., NEAL, O. R. and BRILL, G. D. (1949) Aggregation of the silt and clay soil separates in relation to yield and runoff on coastal plain soils. Proc. Amer. Soil Sci. Soc. 13: 23—26.

25. RUSSELL, E. J. (1950) Soil Conditions and Plant Growth. Longmans, Green & Co. London, N. Y. and Toronto.

26. RYNASIOWICZ, J. (1945) Soil aggregation and onion yields. Soil Sci. 60: 387—396.

27. SIDERI, D. J. (1936) On the formation of structure in soil II. Soil Sci. 42: 462—479.

28. ——————— (1938) On the formation of structure in soil IV Soil Sci. 46: 129—138.

29. SOIL SURVEY STAFF (1951) Soil Survey Manual. U. S. D. A. Bureau of Plants. Ind. Soils and Agric. Eng.

30. WRIGHT, C. H. (1939) Soil Analysis. Thomas Murby & Co. London.

31. YODER, C. H. (1936) A direct method of aggregation analysis of soils and a study of the physical nature of erosion losses. J. Amer. Soc. Agr. 28: 337—350.

32. ZOHARY, M. (1955) Geobotany. Sifriat Poalim-Maanit, Israel.