A Biogeocoenological Approach to the Solution of Land Reclamation Problems

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Biogeocoenological (integrated effect of natural forces i.e. climate, hydrology, plants, etc.) investigations have been carried out in the north-western part of the Precaspian Lowland. The area has an arid climate receiving an average of 280 mm of precipitation annually (155 mm of it during the warm season). Annual potential evapotranspiration is thrice the total precipitation, reaching 800--900 mm. The lowland is composed of heavy loams 15 m thick and nearly uniform in texture over vast areas. Stagnant ground waters occur at a depth of 7 m and vary considerably as to degree of salinity and salt composition, but sodium sulphate commonly prevails. The Precaspian Lowland has flat uneroded topography. About 15% of the total area is occupied by large isolated depressions 1—3 m deep known under the local names "bolshie padiny" and "limany". Their area ranges from 1—2 up to some thousand ha. The rest of the territory has a pronounced micro-relief on an almost flat topography. This microrelief consists of isolated micro-depressions and microknolls (2—3 to 20—30 m wide) with an elevation of 5 to 40 cm. The principal elements of microrelief are: microknolls, microslopes and microdepressions occupying respectively more than 50% and about 25% and 25% of the total area. Such microrelief promotes the redistribution of snow and melt waters and their accumulation in microdepressions. In the springs of wet years large isolated depressions are ponded by melt-waters.

The redistribution of moisture results in a pronounced variability in soils, vegetation, and ground waters and causes the formation of three different types of biogeocenoses according to the elements of microrelief: biogeocenoses of microknolls (BMK), biogeocenoses of microslopes (BMS) and biogeocenoses of microdepressions (BMD).

1. The BMK are characterized by a sparse vegetation represented by *Artemisia pauciflora* and *Kochia prostrata* as dominating species on solonchak-solonetz soils whose profile consists of the surface horizon (about 10 cm thick) with a sharp lower boundary; solonetz horizon (23 cm thick) merging sharply into the first salinized horizon with a permanent low moisture content; second salinized horizon continued by the layer of gypsum accumulation. The root systems of *Artemisia pauciflora* develop only within the solonetz horizon, while the roots of *Kochia prostrata* penetrate to a depth of 3 m, approaching the upper boundary of the capillary fringe. The capillary-fringe commonly occurs at a depth of more than 3 m while the ground water table is found at a depth of about 7 m. The salt distribution pattern in solonchak-solonetz soil is given in Fig. 2.

The soil-forming parent material at a depth of 6 – 7 m from the surface does not seem to be salinized as it contains the same amount of salts as the saturating ground water. The salt concentration in the ground water varies from 10 to 20 g/liter. The conclusion may be drawn that ground waters, rather than the soil-forming parent material, are responsible for the accumulation of salts

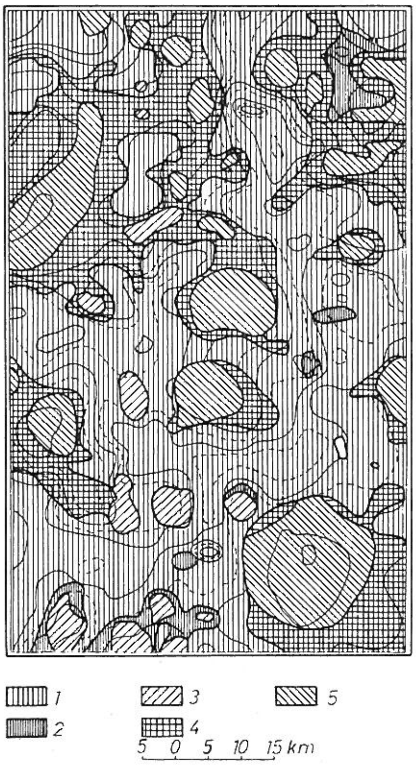

Fig. 1

Soil and microtopographic map of site 3. (60 × 100 m). 1. Solonchakous solonetz soils. 2. Solonetz turning into steppe soil. 3. Light chestnut soils in "zapadinas". 4. Dark-coloured soils. 5. Light chestnut soils of microslopes

in the solonchak-solonetz soils. The water uptake by the roots of *Kochia prostrata* from the upper 3 m layer gives rise to the moisture and suction gradients directed towards the surface including the upward movement of saline waters into the root zone. Moisture consumption by plant roots results in extreme drying and salinization of the layer. The solonchak-solonetz soils receive in the spring about 80 mm of moisture which is sufficient for wetting the profile only to a depth of 35 cm. The value of the moisture deficiency in the fall is as much as 226 mm. Consequently, the considered soils are characterized by non-percolative type of moisture regime accompanied in the lower part of the solum by the upward movement of moisture bringing about the salt accumulation. The average biological productivity of the BMK has been estimated at 8.4 metric centners of the air-dried phytomass per hectare.

2. The BMS are characterized by light-chestnut soils developed under natural grass vegetation with *Pyrethrum achilleifolium* and *Agropyrum desertorum* as the dominant species. Their roots penetrate to a depth of 100 – 120 cm. The salt distribution pattern is given in Fig. 3. It is evident that the upper 100 – 120 cm layer is free of soluble salts. The root zone therefore coincides with the leached horizon. The roots of plants do not reach the horizon of salt accumulation. Salinity of ground waters under microslopes is estimated as 5 – 8 g/liter. In spring the light-chestnut soil receives 144 mm of moisture which is sufficient to wet the profile to a depth of 80 cm on the average and 120 cm at most. As the soil moisture deficiency in the fall is as high as 260 mm,

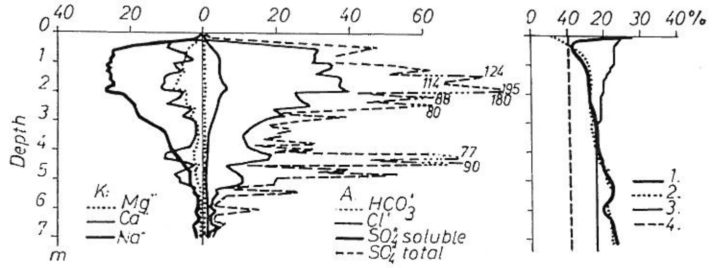

Fig. 2

I. Salt distribution' pattern in a solonchak-solonetz soil. K — cations, A — anions. II. Soil moisture content profile: 1. soil moisture content in spring, 2. moisture content in fall, 3. field capacity, 4. wilting point. (meq./100 g of air-dried soil)

the light-chestnut soils are characterized by a moisture regime of the non-percolative type. Slight upward movements of moisture and salt accumulation have been found to take place only in the subsoil at a depth of 100 – 120 cm, and to be responsible for the low moisture content of this layer. As the root systems do not penetrate deeper than 100 – 120 cm, the rate of salinization in the light-chestnut soils is considerably lower than that in the solonchak-solonetz soils. The biological productivity of the BMS reaches on an average 11.6 metric centners per hectare of air-dried phytomass.

3. The BMD are characterized by the dark chernozem-like soils developed under a tall grass vegetation. The roots of some species *(Spirea hypericifolia, Medicago falcata, Gallium ruthenicum)* penetrate as deep as 3 m. The root systems of other plants develop in the surface layer 1 – 2 m thick. These soils are free of soluble salts but commonly contain calcium carbonate. The salinity of the ground waters is very low (some tenths of g/liter), hydrocarbonates being predominant. The moisture regime of these soils is of the periodically-percolating type, as the mean value of the moisture amount supplied to the soil in the spring, estimated at 332 mm, essentially exceeds the mean soil moisture deficiency estimated at 260 mm. The additional moistening of soils in the microdepressions caused by snow and melt water accumulation induces the thorough wetting of the dark chernozem-like soil profile, leaching soluble salts and causing an accumulation of nonsaline ground water lenses under the microdepressions. The thorough wetting of the soil profile has been found to take place commonly once every two years. The average biological productivity of the BMD is up to 24 metric centners per hectare of air-dried phytomass.

Thus, within the study area, under the same climatic conditions and on the same lithology, three types of biogeocenoses are being formed greatly differing in soils, vegetation, salinity and biological productivity.

A study of the spatial distribution of biogeocenoses in nature is very helpful in working out effective methods of land reclamation. The highest biological productivity was found to be specific for the biogeocenoses of microdepressions due to the additional moistening providing for an adequate moisture supply and the leaching of soluble salts. This can be proved by visual observations in nature. Careful comparative studies of the quantitative characteristics of the biogeocenoses allow a more accurate substantiation

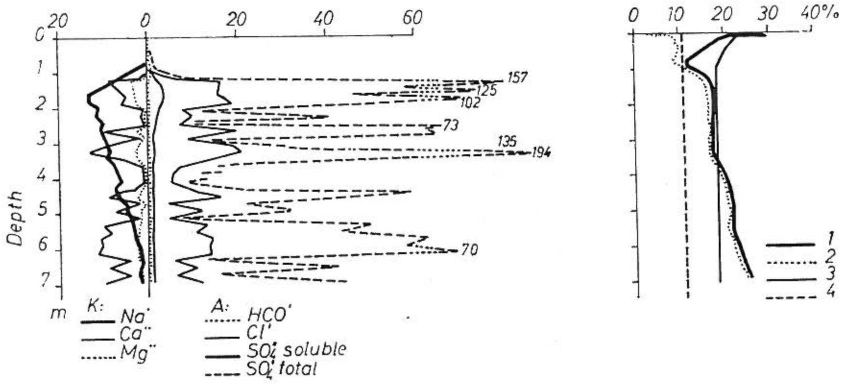

Fig. 3

I. Salt distribution pattern in a light-chestnut soil. II. Soil moisture content profile: 1. soil moisture content in spring; 2. soil moisture content in fall; 3. field capacity; 4. wilting point (meq./100 g of air-dried soil)

of this conclusion. The biological productivity of the BMD is thrice that of the BMK and twice as much as the biological productivity of the BMS. The difference between biogeocenoses would be much more pronounced if one took into account the quality of phytomass which in the BMD was found to be the best. All these differences are caused by the additional supply of moisture to the BMD. An increment in the soil moisture supply in the spring is estimated as follows: in the BMK — 80 mm, in the BMD — 144 mm, in the BMD — 332 mm. Keeping in mind the percentage of the total area occupied by various biogeocenoses, the mean value of an increment in soil moisture may be estimated as:

$$0.5 \times 80 + 0.25 \times 144 + 0.25 \times 332 = 159 \text{ mm}.$$

From the amount of 332 mm of soil moisture supplied to the BMD, 62 mm are lost by infiltration and 270 mm remain in the profile. The value of additional moistening is therefore estimated at 270 — 159 = 111 mm. Such an additional application of moisture is expected to bring about an essential increase in the biological productivity and noticeable improvement of the phytomass quality. Under dryland farming conditions the only source of additional moistening is redistribution and accumulation of snow on the ameliorated plots. Various practical methods can be employed for effective snow retention and accumulation. Good results have been obtained in retaining snow by tree and shrub shelterbelts and strip sorghum plantations streched perpendicularly to the direction of winds prevailing in winter. The species: *Ulmus pennatoramosum*, *Ribes aurea*, *Lonicera tatarica* have been found to be resistant to salts. The area between the shelterbelts was used for growing agricultural crops.

An essential increase in the productivity of the BMK cannot be attained by applying additional moisture as the only measure of soil reclamation. Successful amelioration of solonchak-solonetz soils implies deep plowing (to a depth of 50 cm) aimed at involving the gypsum accumulations that occur at a depth of 35—50 cm. Mixing of the surface soil with gypsum is an indispensable measure of soil reclamation but is effective only when the soil is adequately supplied with moisture. Snow retention by means of shelterbelts increases the soil moisture content in the spring as follows: in the BMK — 196 mm, in the BMS — 236 mm, in the BMD — 325 mm (for the whole area this value will be as high as 238 mm or by 79 mm more than in virgin steppe). These figures are close to those of the soil moisture deficiencies in the fall (234, 282 and 379 mm respectively). In wet years the values of soil moisture increments in the spring exceed those of the soil moisture deficiencies in the fall. The soil moisture regime in the BMK and BMS becomes periodically-percolative which results in leaching salts into the ground waters. During a period of 15 years the total amount of salts in the 7 m layer was decreased in the BMK from 130—150 kg/m^2 to 66—75 kg/m^2 including the decrease in the amount of chlorine from 230—250 g-eq/m^2 to 65—120 g—eq/m^2. The remaining salts have leached into the lower part of the solum.

Table 1

Biological productivity of virgin and reclaimed lands

Types of biogeocenoses	Natural	Under wheat		Shelterbelts total
		total	grain	
	metric centners per hectare			
BMK	4—13	22—30	7— 8	
BMS	7—18	18—44	7— 8	
BMD	22—27	31—75	12—21	
Mean values	10—18	23—42	8—11	23

Amelioration of the BMK and BMS soils makes it possible to bring them into agricultural production. Thus, the natural semi-desert biogeocenoses have been transformed into the agrobiogeocenoses.

The biological productivity of the biogeocenoses of the reclaimed area has been essentially increased. According to observations carried out during 1956—1958, the biological productivity of virgin and reclaimed lands was as shown in Table 1.