Soil chemical properties during succession from abandoned cropland to native range

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Abstract

Succession from abandoned cropland to native range provides the opportunity to study soil transformation in progress from a known date. The purpose of this study was to assess soil transformations under abandoned cropland reverting back to native range in the Brown and Black Chernozemic soil zones of southern Alberta, Canada. Total extractable organic acids and phenols were generally greater in abandoned cropland soils than in adjacent native range soils. Ammonium N increased with succession but nitrate N decreased. Percent identifiable N of hydrolyzable N decreased with time of recovery. Aliphatic carboxylic acids increased quantitatively with succession in the Black soils and decreased in the Brown Chernozemic soils. A change in quality of soil organic matter towards a more complex and stable form occurred with time. Regression analyses of the Brown Chernozemic soils abandoned in 1925, 1927, 1950, and 1975 are interpreted to show that response to years of the chemical characteristics studied was essentially linear. In order to form the type of organic matter that occurs in undisturbed Black and Brown Chernozemic soils, recovery of abandoned cropland may take at least 150 years in the former and 75 years in the latter under moderate grazing.

Key Words: Alberta, Chernozemic soils, organic matter, nitrogen, phenols, organic acids

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Old-field succession is the process whereby cropland is abandoned and allowed to revert to a stable or climax plant community. Large areas of cropland in southern Alberta have been abandoned over the past century during extended periods of low precipitation (Dormaar and Smoliak 1985). This provides an opportunity to examine soil transformations over a given time period.

In a recent study (Dormaar and Smoliak 1985), changes in the vegetation and a number of soil chemical properties during succession from abandoned cropland to native range under semiarid climatic conditions were assessed. However, only 3 fields were studied and all were within the same soil zone. The present study was initiated to investigate soil organic matter and nitrogen recovery processes on abandoned cropland fields located in different soil zones across southern Alberta. As previous studies have indicated that soil nitrogen was greatly affected by old-field successions (Rice 1984, Tilman 1986) and the equilibrium, under which soil organic matter in semiarid soils formed and existed, was fragile (Dormaar et al. 1977), this study seeks to assess the effect of length of time since abandonment on the quality of soil nitrogen and organic matter in a semiarid and a dry subhumid soil zone.

Materials and Methods

Sites

All areas selected for this study included paired sites of abandoned cropland and adjoining native range. The native range and adjacent abandoned cropland had all been grazed by cattle since abandonment at a moderate rate to provide at least a 50% carryover of forage. The management history prior to plowing is not known.

The histories of the abandoned cropland fields are as follows:
Manyberries: Site 1925—The field was plowed in 1910, cultivated for 15 years, and abandoned in 1925. Site 1927—The field was plowed in 1917, cultivated for 10 years, and abandoned in 1927. Site 1950—The field was plowed in 1920, cultivated intermittently for 30 years, and abandoned in 1950. Site 1975—The field was plowed in 1975, seeded to introduced grasses that autumn, then abandoned when introduced grasses failed to establish.
Bow Island: Site 1922. The field was plowed in 1912, cultivated for 10 years, and abandoned in 1922.
Fort Macleod: Sites 1884a and 1884b. The fields were plowed in 1883, cultivated for one year, and abandoned in 1884.
Stavely: Site 1916. The field was plowed in 1915, cultivated for one year, and abandoned in 1916.

Soils

The soils of the Manyberries and Bow Island sites are members of the Orthic Brown Subgroup of the Chernozemic Order (Aridic Ustochrept). Soils of the Fort Macleod and Stavely sites are members of the Rego and Orthic Black Subgroups of the Chernozemic Order, respectively (Entic and Udic Haploborolls). The climates are semiarid and dry subhumid for the Brown and Black Chernozemic soils, respectively. Annual precipitation averages 353, 342, 434, and 472 mm for the 4 sites, respectively (Environment Canada 1982).

Sampling and Preparation

The Ah (=A₁) soil horizon was sampled during April, 1987. Samples (2,000 g) were taken from 4 sampling plots randomly located within each treatment pair. The depths of the Manyberries, Bow Island, Fort Macleod, and Stavely Ah horizons were 7, 9, 14, and 17 cm, respectively. The 4 paired sampling plots were located 5 m from the boundary between abandoned cropland and adjacent native range and 100 m apart. The samples were hand-sieved through a 2-mm screen, and stored in double polyethylene bags at 4° C. At the time of sieving, visible roots and other debris were removed from the soil and discarded. Moisture content of the soil for reporting on dry weight bases was determined gravimetrically by drying a small portion of soil overnight at 105° C.

Analyses

Mineralizable-N, as an index of biological N availability, was determined as outlined by MacKay and Carefoot (1981). After the mineralizable-N analyses, the soils were dried and ground to pass a 0.5-mm sieve. Autoclaveable-N, as an index of chemical N availability, was determined as described by Keeney (1982). Urease activity was determined on air-dried soils at pH 9.0 according to Tabatabai and Bremner (1972). Total nitrogen (N) was determined as outlined by the Association of Official Agricultural Chemists (1965) and hydrolyzable-N, amino acid-N, and amino sugar-N by methods described by Stevenson (1982). Nitrate N (NO₃-N) and ammonium N (NH₄⁺-N) were determined by steam distillation (Keeney and Nelson 1982). The Folin-Ciocalteu reagent was used to determine the total content of soluble phenolic compounds (Association of Official Agricultural Chemists 1965, Morita 1980).

The method used for studying aliphatic carboxylic acids and phenols was developed from those outlined by Jalal and Read (1983), Pierce Chemical Company (1985), and Vance et al. (1985). The initial step involved extracting the organic compounds from 50 g of each sample from each sampling plot using Na₄P₂O₇ at pH 10 and acidifying the extract to pH 2.5 with H₂SO₄ (Vance et al. 1985). The extracts of the 4 plots/field were combined in order to reduce the number of analyses on the mass spectrometer. The acid-soluble organic substances were analyzed for organic acids and phenolic compounds; the acid-insoluble organic substances were analyzed for aliphatic carboxylic acid.

The acid-soluble organic matter was decanted into a separatory funnel. The dicarboxylic acids and phenols were extracted by liquid-liquid extraction using 3 times 100 ml diethyl ether, and the ether extracts transferred to a 500-ml wide-mouth Erlenmeyer flask. Following the addition of 5 g of anhydrous MgSO₄ for drying the ether extract, the mixture was stirred for 5 min and filtered (Whatman #54). The filtrate was reduced to 1 ml on a rotary evaporator (40° C, 50 kPa), transferred with methanol into a small vial, reduced to 200 µl with a stream of N₂, 100 µg of 3-methoxybenzoic acid added to serve as internal standard and the mixture evaporated to dryness with a stream of N₂. To obtain

Table 1. Nitrogen characteristics and total phenol content of the Ah horizons of paired abandoned cropland/native range sites across southern Alberta.

	Manyberries					Regres- sion ⁴	Bow Island		Fort Macleod		Stavely	
	Native (n=16)	Abandoned (n=4)					Native (n=4)	Aband. (n=4)	Native (n=8)	Aband. 1884	Native (n=4)	Aband. (n=4)
		1925	1927	1950	1975			1922		1884		1916
Urease activity ¹	237	236	212**	198**	87**	LQ	248	203**	270	222**	296	176**
Total N (%)	0.150	0.136*	0.135*	0.119**	0.104**	L	0.160	0.131**	0.430	0.358**	0.908	0.354**
Mineralizable N (μg/g of soil) ²	10.2	9.5	8.2	7.5*	6.5**	L	10.6	9.3	33.0	23.2**	47.3	22.0**
Chemical index ³ (μg/g of soil)	55.1	54.7	53.2**	48.3**	34.2**	LQ	54.7	46.9**	165.8	112.8**	238.2	188.6**
Hydrolyzable N (% of total N)												
Total	79	79	80	83	87*	L	80	81	75	76	76	78
Amino acid	35	36	38**	45**	52**	L	31	35*	28	33**	22	37
Amino sugar	7	8	8	11	15**	L	12	12	13	14	13	16
Ammonium	12	13	13	17*	18*		11	12	15	16	7	14*
Total identified	54	57*	59*	73**	85**	L	54	59**	56	62**	42	67*
Exchangeable N (μg/g)												
NH ₄ ⁺ -N	6.2	6.3	6.1	5.4*	3.4**	LQ	6.8	6.7	8.6	8.1**	9.2	6.2**
NO ₃ ⁻ -N	3.3	3.5	3.6	6.5**	7.4**	LQ	3.3	3.5	4.6	5.3	4.5	4.7
Phenols (mg/kg)	287	285	281	293	387**	LQ	397	358*	1104	839**	2006	1619*

***Significantly different from corresponding native range values at 0.05 and 0.01 levels of probability, respectively.

¹NH₄⁺-N released, µg/g of dry soil per 2 hours.

²Change of (NH₄⁺ + NO₃⁻)-N from two successive incubations of 1 and 2 week periods.

³NH₄⁺-N released on autoclaving.

⁴Linear (L) and quadratic (Q) regressions significant at P≤0.05.

silylation (Jalal and Read 1983, Pierce Chemical Company 1985), the residue was dissolved in 100 μ l pyridine and 100 μ l N, O-bis(trimethylsilyl)trifluoroacetamide (BSTFA). To ensure complete derivatization, the sample mixture was heated at 80° C in the closed vial for 10 min.

The acid-insoluble organic matter was mixed with 100 ml methylene chloride for 5 min and decanted into a separatory funnel. The methylene chloride plus 2 subsequent 50-ml methylene chloride washings were transferred to a wide-mouth Erlenmeyer flask. Following the addition of 5 g of anhydrous $MgSO_4$ for drying the methylene chloride extract, the mixture was stirred for 5 min and filtered (Whatman #54). The filtrate was reduced to 2 ml on a rotary evaporator (40° C, 60 kPa), transferred with methylene chloride into a small vial, 80 μ g of tricosanoic acid added to serve as internal standard, and the mixture evaporated to dryness with a stream of nitrogen. Esterification was achieved (Pierce Chemical Company 1985) with the addition of 0.5 ml of a mixture of N,N-dimethylformamide-dimethyl acetal (9:1). To ensure complete solution and reaction, the sample mixture was heated at 60° C in the closed vial for 10 min.

Initial analyses were carried out with a Hewlett Packard GC 5840A, using a 12-m long capillary column wall-coated with cross-linked methyl silicone for the aliphatic carboxylic acid methyl esters and a 30-m long capillary column wall-coated with 5% diphenyl-95% dimethyl polysiloxane (DB-5) for the dicarboxylic acids and phenols. The qualitative analyses were carried out with a Hewlett Packard GC-MS 5985B. Identifications were based on the search of the GC-MS data system and, where possible, authentic samples.

It is recognized that chemical changes occurring within and on the soil are undoubtedly affected by a host of environmental changes that vary with years. Ideally, the most accurate assessment of such changes could be made from repeated analyses of samples taken periodically from well-replicated field plot tests over many years. Although replication and application of current statistical analyses to newly established field plot experiments is common and undeniably desirable and useful, valid information and data can still be gained from early established, unreplicated field experiments, including drill of abandoned crop studies, by virtue of their

antiquity (Ridley and Hedlin 1968, Dormaar and Pittmann 1980, Dormaar 1983, Dormaar and Smoliak 1985). Time has exerted a type of replication on the drill of the abandoned cropland study described here.

For each abandoned cropland vs. native range pair, analyses of variance were carried out on the nitrogen characteristics and total phenol data. Since the tests were not replicated, the sampling error was used to test the treatment effects. For the Manyberries area, regression analyses were carried out to relate the observed soil characteristics to the number of years since cropland was abandoned. Since the within-field estimate of variation was not appropriate for testing whether the regressions were significant, the estimate between field variation obtained from the native range samples was used for significance tests. Even though there was loss of statistical elegance by combining the organic acid and phenol extracts, the qualitative trends supply valuable information.

Results

Regression analyses of soil characteristics against number of years since cropland was abandoned were interpreted to mean that, except for hydrolysable ammonium N, the response to years was linear with the variables urease activity, chemical index, NH_4^+ -N, NO_3^- -N, and phenols possibly having a curvilinear response (Table 1).

The soil data of the 4 native ranges sites at Manyberries were statistically similar, and thus they were averaged (Table 1). The 2 abandoned croplands and 2 native range fields of the Fort Macleod site were statistically similar.

For many variables there were no differences between soil samples from native range and its adjacent field abandoned in 1925 at Manyberries. In the fields abandoned more recently at Manyberries, the difference increased and became more significant as the years since abandonment decreased. Conversely, the data from the 1884 field from Fort Macleod and the 1916 field from Stavely were generally significantly different from those from the adjacent native range. The data from the 1922 field from Bow Island fell generally in between these extremes.

Some measured parameters were lower in the abandoned croplands while others were higher compared with the native range

Table 2. Organic acids and phenols (ng/g of soil) identified in the $Na_4P_2O_7$ -soluble, H_2SO_4 -insoluble fraction from the Ah horizons of paired abandoned cropland/native range sites across southern Alberta.

	Manyberries					Bow Island		Fort Macleod			Stavely	
	Native	Abandoned				Native	Abandoned	Native	Abandoned		Native	Abandoned
		1925	1927	1950	1975		1922		1884a	1884b		1916
Benzoic acid	598	590	547	423	266	614	550	212	186	191	129	119
Succinic acid	372	376	375	383	731	381	385	1450	1620	1610	2720	2840
Fumaric acid	58	64	62	117	124	62	63	99	101	104	125	136
Nonanoic acid	632	591	574	490	104	646	621	132	112	116	72	61
?	187	188	188	197	207	190	194	29	39	38	21	28
?	138	144	140	157	196	142	144	16	21	20	11	14
Phenylactic acid	181	175	177	123	107	175	170	394	292	287	436	381
Pinelic acid	136	136	134	133	123	134	130	126	113	116	110	107
4-(OH) benzoic acid	416	417	434	497	700	421	435	371	446	453	362	485
Suberic acid	92	101	149	254	289	86	85	292	329	338	304	348
3-(OH) Phenyl propionic acid	99	106	110	396	413	104	110	29	38	36	29	41
Vanillic acid	230	236	248	256	281	225	338	113	144	148	96	124
Azelaic acid	85	88	143	509	662	94	101	698	710	718	762	802
3,4-(diOH) benzoic acid	81	74	65	61	47	94	89	30	12	16	12	11
Sebacic acid	64	62	105	120	122	69	74	56	41	39	12	30
?	61	67	69	91	108	68	74	122	161	164	129	148
12-(OH) dodecanoic acid	67	67	71	72	82	68	73	24	22	22	16	11
Total μ g/g soil	3.5	3.5	3.6	4.3	4.6	3.6	3.6	4.2	4.4	4.4	5.4	5.7

Table 3. Trimethylsilylated aliphatic carboxylic acids ($\mu\text{g/g}$ of soil) identified in the $\text{Na}_4\text{P}_2\text{O}_7$ -soluble, H_2SO_4 -insoluble fraction from the Ah horizons of paired abandoned cropland/native range sites across southern Alberta.

Carbon no.	12:0	14:0	16:1C	16:0	17:0	18:1C	18:0	19:0	20:0	21:0	22:0	23:0	24:0	25:0	26:0	28:0	29:0	30:0	Total
Manyberries																			
Native	16	12	17	32	3	9	17	17	6	42	11		7	5	2	2	12	1	211
Abandoned:																			
1925	15	11	19	34	3	11	18	16	5	40	10		8	6	3	1	13	1	214
1927	13	11	20	34	4	11	19	16	5	39	10		8	8	3	1	13	1	216
1950	9	9	29	46	5	20	55	8	4	11	2		10	10	4	—	14	2	238
1975	3	8	32	93	7	25	98	3	3	1	—		13	11	5	—	15	3	317
Bow Island																			
Native	9	12	16	34	3	11	20	17	5	40	10		6	6	2	2	14	1	208
Abandoned:																			
1922	9	11	17	39	4	14	23	15	5	37	9		7	8	2	1	16	1	218
Fort Macleod																			
Native	5	54	20	265	2	62	98	4	3	—	—		17	—	—	20	62	12	624
Abandoned:																			
1884a	2	18	30	151	1	27	34	2	2	—	—		27	—	—	9	19	11	331
1884b	2	17	31	149	2	25	36	2	2	—	—		24	—	—	9	22	11	329
Stavelly																			
Native	6	74	21	283	2	69	114	6	4	—	—		16	—	—	19	66	11	691
Abandoned:																			
1916	2	32	36	148	1	25	27	4	3	—	—		30	—	—	6	23	10	347

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soils. The most pronounced contrast was with the exchangeable N: $\text{NH}_4^+\text{-N}$ increased with time of recovery whereas $\text{NH}_3^+\text{-N}$ decreased towards equilibrium (Table 1). Percent identifiable N of hydrolyzable N decreased with time of succession. This indicates a change in the quality and complexity of the soil N as soil N changed into a non-hydrolyzable, more stable form over time.

Autoclavable-N, as an index of chemical N availability, and potentially mineralizable-N, as an index of biological availability, were highest in the native range soils (Table 1). The urease activities also followed the same pattern from recently abandoned cropland to native range. Hence, urease activity and the chemical index, which was simpler and more rapid than the biological approach to N availability, may be more desirable methods for establishing different pools within overall N. Total phenols (Table 1) decreased with time in the Manyberries soils and increased in the other soils.

By using gas chromatography many compounds were shown to exist in the various extracts. Concentrations of these compounds ranged from 11 to 2,840 ng/g of soil. Succinic, pimelic, suberic, azelaic, and sebacic acids are all saturated dicarboxylic acids. Fumaric is an unsaturated dibasic acid. The sums of these identified organic acids and phenols overall increased from the Brown to the Black Chernozemic soils even though this did not always hold for individual compounds. This total was generally greater in abandoned cropland soils than in the adjacent native range soils, confirming a more complex type of organic matter in these latter soils. However, the 1975, 1950, 1927, and 1925 abandoned cropland soils sequence vs. the native range soil comparison at Manyberries illustrates the difficulty in interpreting the results of the individual compounds. Overall, benzoic, succinic, nonanoic, 4-(OH) benzoic, and vanillic acids were the most important acids identified.

Quantitatively, the soils contained more organic acids in the $\text{Na}_4\text{P}_2\text{O}_7$ -soluble, H_2SO_4 -insoluble fraction than in the H_2SO_4 -soluble fraction of the organic matter (Table 3 vs. Table 2). Although there were fewer major identifiable aliphatic carboxylic acids in the Black than in the Brown Chernozemic soils, the Black Chernozemic soils nevertheless had larger total values (Table 3). Another major difference between the Brown and Black Chernozemic soils was the quantitative increase of aliphatic carboxylic acids during transformation in the Black and decrease in the

Brown Chernozemic soils. Aliphatic carboxylic acids with C number 12:0, 17:0, 19:0, 20:0, 21:0, 22:0, 25:0, 25:0, and 26:0 were quantitatively more prevalent in the Brown than in the Black Chernozemic soils. Aliphatic carboxylic acids with C number 16:0, 18:1C, 18:0, and 29:0 decreased during transformation in the Brown but they increased in the Black Chernozemic soils.

Discussion

The pairs of native range vs. abandoned cropland could not be replicated by year because similarly treated nearby abandoned fields were not available. The Fort Macleod site, with duplicate fields, was a fortunate coincidence. Since the soil data among the 4 native range sites at Manyberries and among the 2 native range sites at Fort Macleod demonstrated good agreement, the data from the abandoned cropland fields were felt, therefore, to be representative of their position in time.

Vreeken (1975) noted that for the development of a specific soil in a given soil landscape, it is necessary to identify 2 aspects of time. First, there is the duration of soil development within a given set of soil-forming factors. Secondly, there is the historical context within which pedologic and geomorphic processes were and are taking place. The present study deals with a sequence of soils that began transforming because of a changing set of soil-forming factors at different moments in the past and are still approaching the state of soil existing under the adjacent native range. Such chronosequences can be used for inferences on pathways of soil organic matter transformations and rates of soil development if it can be assumed, through the principle of uniformitarianism, that soil history repeats itself throughout time regardless of the moment of incipience. Not only have the soils under discussion developed under essentially constant macro-environmental conditions, the history of the abandoned fields prior to abandonment will essentially have affected only the rate and not the pathway of recovery.

One would expect that the length of time land was in cultivation and the cultural treatments imposed would influence the chemical composition and, therefore, the time for recovery. This aspect could not be examined with the present study because the time since abandonment and years of cultivation were confounded. However, the most drastic changes in the chemical composition of soils would occur in the first year of cultivation (McGill et al. 1981). This effect may have influenced the recovery trends observed with

the Manyberries soils which were cultivated for more than 10 years, except for the soil abandoned in 1975 which had been cultivated for only 1 year. The effects of longer cultivation might be to produce greater contrasts than were presently found and result in more trends, among the chemical constituents studied, that are non-linear.

The data measured the net effects of disturbance, caused by cultivation and erosion, and recovery through the formation of well-humidified organic matter from various types of vegetation. Although the type of vegetation can affect the quantity and quality of soil organic matter (Neal 1969, Rice 1984), the present study only addressed the soil chemical properties as found at a given moment regardless of how they got there. Nevertheless, valuable information on the effects of time of soil chemical transformations may be obtained.

Urease is involved in the chemical transformation of N in the soil and is primarily produced by microbial and fungal organisms. It was very low in the Manyberries 1975 field, whereas its activity had fully returned in the 1925 field. Conversely, the urease activity of the Black Chernozemic soils at Fort Macleod and Stavely had not recovered fully at the time of this study. Since this gradient in urease activity occurred regardless of the hydrothermal conditions, the increase is likely to be universal, at least under grassland conditions.

Even though hydrolyzable N as percent of total N was near equilibrium, except for the very recently abandoned Manyberries 1975 field, the percent N of hydrolyzable N identified always decreased with time of recovery. Soil N has, therefore, been incorporated into a much more stable type of soil organic matter.

The increase in $\text{NH}_4^+\text{-N}$ and decrease in $\text{NH}_3\text{-N}$ with time (Table 1) supports the theory that climax species inhibit nitrification (Rice 1984). There is growing evidence that many plant species can use $\text{NH}_4^+\text{-N}$ as effectively as or more so than $\text{NO}_3^-\text{-N}$ in climax situations (Rice 1984). This inverse relationship between the amounts of $\text{NO}_3^-\text{-N}$ and $\text{NH}_4^+\text{-N}$, i.e., the amount of $\text{NO}_3^-\text{-N}$ decreases from a high while $\text{NH}_4^+\text{-N}$ increases from a low in the first successional stage to a low or high value, respectively, in the climax, substantiates not only our earlier findings (Dormaer and Smoliak 1985) but also those of Rice (1984) and Tilman (1986) even though the present results cover 2 separate soil zones. Rice (1984) established that counts of nitrifiers decreased towards the climax stage and hypothesized that to conserve N the nitrifiers were inhibited under the climax vegetation, thus preventing the oxidation of $\text{NH}_4^+\text{-N}$ to $\text{NO}_3^-\text{-N}$. The excess $\text{NH}_4^+\text{-N}$ is absorbed onto the exchange complex of the soil, thereby becoming less susceptible to leaching.

Soil organic matter is a mixture of many low- and high-molecular weight aliphatic and aromatic compounds and complexes. Extensive suites of compounds can thus be obtained from the soil as evidenced by the present results (Tables 2 and 3). Aliphatic carboxylic acids are major components of many organisms and will, therefore, be important contributors to extractable soil organic matter. They are also considered to be one of the possible causes of inhibition of germination and shoot growth leading to reduced productivity (Rice 1984). However, many of the aliphatic carboxylic acids are also chemically stable and persist for long periods of pedological and geological time. Although fingerprint patterns have been discussed for Chernozemic soils (Dormaer 1982), from the current results it seems logical to concentrate future research on the behavior of only some of the major aliphatic carboxylic and other acids in terms of recovery of abandoned cropland. These may include benzoic, succinic, nonanoic, 4-(OH) benzoic, and vanillic acids.

Phenolic compounds exist in the soil and have been studied for their possible role in the solubilization and transport of metal ions during podzolization (Vance et al. 1985) and allelopathic effects (Rice 1984). Although less downward transport occurs in grass-

land than in forested soils, phenolic compounds may play an important role in stabilizing metal ions, thereby affecting mineral nutrition, during recovery of abandoned cropland (Dao 1987). The increased phenol levels in the more recently abandoned soils (Table 1) are consistent with inhibited growth in the presence of specific invader species (Rice 1984).

Soil temperature and moisture help control the effect and duration of the biological responses in and on the soil (Pauli 1967). Black Chernozemic organic matter is more stable and, thus, less available for decomposition than Brown Chernozemic organic matter (Dormaer 1975). Up to 39% of the organic matter of the Brown Chernozemic soils was still in an undecomposed form, compared with 5% in the Black Chernozemic soils (Dormaer 1977). Volkovintser (1969) noted that drought reduced biological decomposition and thus led to large amounts of dead roots in soils. Further, the organic matter of the Black Chernozemic soils was also much more resistant to decomposition by derivative thermogravimetry than was that of the Brown Chernozemic soils (Lutwick and Dormaar 1976). That is, the intensity of the humification process gradually decreased with increasing soil aridity, making it easier for abandoned cropland to reach that organic matter quality level. Anderson et al. (1974) further noted that organic matter of dry soils was made up of partially decomposed residues and simple, relatively low molecular weight humic materials, with minimal condensation of aromatic structures and readily mineralized nutrient components.

Conclusions

Results from the study indicate that it will be easier for abandoned cropland on Brown Chernozemic soils to reach the organic matter quality of undisturbed soils than for abandoned Black Chernozemic soils. In order to form the type of organic matter in Black Chernozemic soils that is more stable than that in Brown Chernozemic soils, recovery of abandoned cropland through natural succession and under moderate grazing may take 75 years in the latter and at least 150 years in the former.

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