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Potassium Potential of the Soils of the Gevaş Region in Eastern Anatolia

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Abstract: Due to its semi-arid climate and sloping topography, Eastern Anatolia has limited soil resources for agriculture, strongly necessitating sustainable land management. Fertile soils occur only in limited areas such as the Gevaş region, where sugar beet is one of the main crops with a particular need for K. Unfortunately, studies on the non-exchangeable (slowly available) and exchangeable K contents, along with soil properties such as clay mineralogy, organic matter content and texture, which are closely related to soil production potential, are not sufficient in the region. Thus, 40 soil samples out of 7 soil series were collected for the determination of the K - potential of the region. Results revealed that the non-exchangeable K (potential) of the Gevaş region soils has predominantly originated from illite and exchangeable K (available) from organic matter and illite. The exchangeable potassium levels for Hasbey II, Yuva, Yemişlik II, Orak and İskele and Yemişlik, Hasbey, Hasbey III, Güzelkonak, Güzelkonak II are determined to be sufficient for the present non-intensive agriculture, but for the Mülk soils there is a need for K fertilisation. The results of this study are expected to partly relieve the low – income farmers of the area from the economical burden of fertilization for K practiced in the present non – intensive agriculture.

Key Words: K - potential, Clay mineralogy, Eastern Anatolia.

Doğu Anadolu'da Gevaş Bölgesi Topraklarının Potasyum Potansiyeli

Özet: Doğu Anadolu yarı kurak iklimi ve eğimli topoğrafyası nedeniyle tarım için kısıtlı toprak kaynaklarına sahip olması güçlü iyi bir yönetim ve sürdürülebilir tarım gerektirmektedir. Verimli topraklar, özellikle K' a gereksinim duyan şeker pancarının ana ürün olduğu Gevaş Bölgesi gibi yalnızca sınırlı alanlarda bulunmaktadır. Değişmeyen (yavaş yararlı) ve değişebilir K içeriğiyle kil mineralojisi, organik madde ve tekstür gibi toprağın üretim kapasitesiyle yakından ilgili toprak özellikleri bölgede yeterince çalışılmamıştır. Bu nedenle bölgede 7 toprak serisine ait toplam 40 toprak örneği K potansiyelinin saptanması için alınmıştır. Sonuçlar Gevaş bölgesi topraklarındaki değişmeyen (potansiyel–depo) K' un toprakların illit içeriğinden, değişebilir (alınabilir) K'un ise organik maddeden ve illitten kaynaklandığını ortaya koymuştur. Hasbey II, Yuva, Yemişlik II, Orak ve İskele ve Yemişlik, Hasbey, Hasbey II, Güzelkonak, Güzelkonak II serilerinde güncel tarım uygulamaları için değişebilir K düzeyleri yeterli bulunmuş, buna karşın Mülk serisinde K gübrelemesine gereksinim olduğu saptanmıştır. Bu çalışmanın sonuçları beklenildiği gibi kısmende olsa düşük gelirli çiftcilerin K gübrelemesinden kaynaklanacak yüklerini hafifletecektir.

Anahtar Sözcükler: K – potansiyeli, kil minerojisi, Doğu Anadolu.

Introduction

Soil potassium potential directly affects crop yield since potassium is responsible for the maintenance of osmotic pressure and cell size, which in turn influences photosynthesis and the energy production along with stomatal opening and carbon dioxide supply. Potassium is assimilated in relatively large quantities by the growing crop as the yield and quality of the sugar beet are closely related to soil K potential (Tisdale et al., 1993; Marschner, 1995).

Turkish soils were earlier assumed to have sufficient potassium for agriculture, whereas recent studies undertaken in Central Anatolia (Munsuz et al., 1996), Eastern Anatolia (Karaçal and Çimrin, 1996) and the

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Eastern Mediterranean (Geyik and Yılmaz, 2000) regions revealed that the actual potassium status of the soils was insufficient for higher yields. The soils of the Gevaş region are mainly under sugar beet cultivation, necessitating the determination of their non-exchangeable and exchangeable potassium contents for sustainable land management. However, the potassium potential of the soils, as determined by soil analysis, may not give sufficient information on the level of the readily available soil potassium unless this is related to the clay content and to the clay minerals (IPI, 2002), whereas the organic matter content of the soils is also responsible for retaining the readily available potassium (Sparks, 1987). Many studies on the potassium potential of the soils have suggested that illitic clay minerals were the main domains for extractable potassium (Pal, 1985; Güzel et al., 2001) together with the slight effect of organic matter (Mengel and Kirkby, 2001).

The determination of the non-exchangeable and exchangeable potassium status of the Gevaş soils in relation to organic matter and clay minerals within this study will improve the fertiliser use and soil management policy in the area, where soil resources are limited due to topographic and climatic conditions.

Materials and Methods

Soils of the Gevaş region (E. Anatolia) are developed on lacustrine - Lake Van - (Hasbey and Yuva), alluvial (Yemişlik, Güzelkonak, İskele), mudflow-alluvial fan (Orak), and delta (Mülk) terraces of the Plio-Quaternary, which are the transported units of the Bitlis massif's ophiolitic and metamorphic formations, cut by Holocene river valleys.

A total of 40 samples out of 7 soil series classified as mollisols and entisols (Soil Survey, 1999) (Table 1) were collected following a soil survey undertaken in an area of 578 km^2 in Gevaş, located to the south of Lake Van, with annual precipitation of 478.2 mm and an average temperature of 8.9 °C (TOPRAKSU, 1971). Analyses were undertaken for soil pH (Soil Salinity, 1954), CEC and exchangeable bases (determined by atomic absorption spectrometry) (Thomas, 1982), organic matter (Walkley and Black, 1934) and texture (Bouyoucus, 1951). Clay minerals were determined (Jackson, 1979) by X-ray diffractometry at 3-13 (2θ) on Mg^{++} saturated and 550 °C heated K^+ saturated randomly oriented slides (Güven et al., 1980). Exchangeable (available) K was determined according to Thomas (1982), and the non-exchangeable (slowly available/potential) K was determined according to Güzel and Ortaş (1989) at 5 g of soil mixed with 50 ml of 0.3 N HCl, with subsequent shaking for 30 min and centrifuging for 10 min. The clear supernatant liquid was decanted into a 50 ml flask, and the K concentration was determined by AAS. Seven successive extractions were made, and the first was discarded to eliminate the exchangeable K content. Moreover, the soils were classified according to their potassium index groups (Cooke, 1982) for the evaluation of the available K contents of soils according to their crop pattern.

Results

The pH of the soils studied varies from 5.12 to 7.94 due to their ophiolitic character. The relatively high levels of organic matter content in the surface horizons (Table 1), which may be attributed to the low temperatures inhibiting decomposition (Stenberg et al., 1988; Lomander, 2002), decrease with depth. The CEC of the soils varies from 13.35 meq 100 g^{-1} (Mülk series, sandy-clayey loam) to 48.66 meq 100 g^{-1} (Yemişlik series, clayey), and is dominated by exchangeable Ca^{+2} + Mg^{+2}. The clay fraction is mainly composed of smectite, followed by illite and kaolinite (Table 2). The abundance of smectite may be attributed to the soil forming materials of sedimentary origin. The organic matter contents of the surface horizons of the soils (0.7–6.94%), except for the Mülk soils (1.82%), are slightly higher than the average organic matter contents of Anatolian soils (Dinç et al., 1997). This may be attributed to the temperate climatic conditions of the Gevaş region, which inhibit the decomposition of organic matter. The low organic matter content of the Mülk soils (deltaic formation) along with the low CEC, is most probably due to their sandy texture (Table 1).

Non-exchangeable, Exchangeable Potassium and K Index Groups of the Soils

The non-exchangeable potassium levels for all soil samples generally showed a decreasing trend with successive extractions, especially following the third extraction (Table 3). The last, namely the sixth, extraction values of soils decreased to 1.0 mg 100 g^{-1} in the Mülk soils, and to 3.5 mg 100 g^{-1} in the Hasbey II soils, from

Table 1. Some chemical and physical properties of the Gevaş soils*

Horizon	Depth (cm)	pH	CEC meq $100g^{-1}$)	Exchangeable Cations (meq 100 g^{-1})			Org.Mat (%)	Mineral Fraction (%)		
				Na^+	K^+	$Ca^{++}+Mg^{++}$		Sand	Silt	Clay
Hasbey Series (Typic Haploxeroll)										
Ap	0-12	7.78	19.24	0.14	0.58	18.52	2.61	35.96	34.18	29.86
A2	12-30	7.75	20.30	0.14	0.54	19.62	2.81	38.83	29.43	31.75
Bw1	30-55	7.76	20.84	0.13	0.44	20.27	1.88	35.20	31.29	33.51
Bw2	55-85	7.74	22.98	0.12	0.43	22.43	3.02	38.52	27.53	33.95
C	85+	7.72	19.24	0.14	0.45	18.65	2.35	35.85	29.00	35.15
Hasbey II Series (Typic Haploxeroll)										
Ap	0-12	7.57	33.68	0.15	2.14	31.39	6.10	34.82	8.49	56.69
A2	12-30	7.61	25.12	0.11	1.38	23.63	2.68	47.25	23.54	29.22
Bw1	30-55	7.67	23.51	0.11	0.72	22.68	2.50	38.44	23.67	37.89
Hasbey III Series (Typic Haploxeroll)										
Ap	0-15	7.69	34.21	0.14	0.78	33.29	3.15	31.90	31.22	36.88
A2	15-30	7.64	26.72	0.13	0.67	25.92	2.81	27.06	41.74	31.21
Bw1	30-44	7.77	27.26	0.12	0.68	26.46	2.21	26.04	34.10	39.86
Yuva Series (Calcic Haploxeroll)										
Ap	0-11	7.57	33.14	0.14	1.13	31.87	3.22	29.29	21.47	49.23
Bw1	11-30	7.45	35.82	0.21	1.33	34.28	3.28	29.94	21.31	48.75
Bwk2	30-42	7.85	28.33	0.16	0.58	27.59	1.68	27.74	22.08	50.19
Bwk3	42-63	7.81	32.61	0.24	0.56	31.81	1.41	28.03	22.44	49.53
C1	63-77	7.73	29.40	0.14	0.23	29.03	0.70	40.23	17.97	41.81
C2	77+	7.94	33.68	0.17	0.32	33.19	0.56	41.91	17.33	40.75
Yemişlik Series (Vertic Xerofluvent)										
Ap	0-17	6.78	48.66	0.17	0.63	47.86	4.16	27.24	23.57	49.19
Ad	17-35	6.02	46.52	0.18	0.39	45.95	1.53	27.30	17.91	54.79
A3	35-54	6.10	43.31	0.17	0.36	42.78	1.87	24.04	21.88	54.08
AC	54-78	6.27	47.58	0.16	0.47	46.95	1.74	20.28	21.93	57.80
C	78+	5.93	48.66	0.16	0.52	47.98	1.18	9.29	23.72	67.00
Yemişlik II Series (Vertic Xerofluvent)										
Ap	0-16	6.44	47.58	0.19	1.06	46.33	6.94	21.73	27.77	50.50
Ad	16-34	5.85	46.52	0.17	0.64	45.71	1.53	26.83	20.33	52.83
A3	34-57	5.12	45.44	0.18	0.35	44.91	2.15	26.16	21.53	52.30
Orak Series (Calcic Haploxeroll)										
Ap	0-14	7.68	37.95	0.09	1.16	36.70	2.56	37.09	20.44	42.47
Bw	14-30	7.48	39.03	0.11	0.80	38.12	2.50	31.08	21.15	47.77
Bwk2	30-46	7.62	35.82	0.13	0.55	35.14	2.01	39.69	13.42	46.88
Ck	46-70	7.56	35.82	0.15	0.51	35.16	1.25	27.92	21.36	50.73
Ck2	70+	7.74	28.33	0.10	0.32	27.91	2.56	48.34	16.31	35.35
Guzelkonak Series (Typic Haploxeroll)										
Ap	0-12	7.74	36.88	0.11	0.64	36.13	0.90	40.06	21.16	38.78
Ad	12-31	7.46	36.88	0.09	0.63	36.16	3.61	39.95	20.75	39.30
A3	31-57	7.67	31.54	0.11	0.33	31.10	3.15	35.81	30.00	34.19
A4	57-86	7.67	31.54	0.11	0.30	31.13	1.26	43.39	19.11	37.51
Guzelkonak Series II (Typic Haploxeroll)										
Ap	0-15	7.66	28.33	0.09	0.66	27.58	0.77	45.34	21.16	33.51
Ad	15-35	7.90	26.19	0.11	0.42	25.66	2.46	36.51	28.16	35.33
A3	35-60	7.88	22.98	0.13	0.29	22.56	1.68	36.94	27.28	35.78
İskele Series (Lithic Xerorthent)										
Ap	0-13	7.71	35.82	0.08	1.03	34.71	1.68	31.38	33.36	35.27
Mülk Series (Typic Xerorthent)										
A1	0-13	7.78	15.49	0.10	0.28	15.11	1.82	59.70	15.71	24.59
A2	13-25	7.93	13.35	0.10	0.20	13.05	0.70	55.57	20.01	24.41

* Analyses were undertaken as 2 replications and are mean values.

Table 2. The clay mineralogy of the selected soil samples

Horizon	Depth	Clay Mineralogy		
		Smectite	Illite	Kaolinite
Hasbey Series (Typic Haploxeroll)				
Ap	0-12	+++	++	++
A2	12-30	+++	++	++
Bw1	30-55	+	++	++
Yemişlik Series II (Vertic Xerofluvent)				
Ap	0-16	++	++	+
Ad	16-34	++	++	+
A3	34-57	++	++	++
Orak Series (Calcic Haploxeroll)				
Ap	0-14	+++	++	++
Bw	14-30	++	++	+
Bwk2	30-46	+	+	+
Güzelkonak Series II (Typic Haploxeroll)				
Ap	0-15	+	+++	++
Ad	15-35	+	+++	++
İskele Series (Lithic Xerorthent)				
Ap	0-13	++	++	++
Mülk Series (Typic Xeropsamment)				
A1	0-13	+++	++	++
A2	13-25	+++	++	+++

+++ Abundant ++ Moderate +Trace

initial values of 27.9 mg 100 g^{-1} in the latter and 12.7 mg 100 g^{-1} in the Yuva soils (Table 3).

The highest non-exchangeable potassium and organic matter contents were determined in the Hasbey II soils' Ap (0-12 cm) horizon as 84 mg 100 g^{-1} and 6.10 %, respectively, whereas the lowest non-exchangeable K was determined in the Mülk soil series' A2 (13-25 cm) horizon as 17.1 mg 100 g^{-1} together with low levels of organic matter (Tables 1 and 3).

The exchangeable potassium contents of the soils ranged from 7.8 mg 100 g^{-1} (Mülk series) to 84 mg 100 g^{-1} (Hasbey II series) (Table 3). The non-exchangeable and exchangeable K contents showed a decrease with depth for almost all soils, like the K and organic matter contents (Tables 1 and 3).

Correlation analyses revealed that the potassium contents of the soils studied were more related to organic matter than to the amount of the clay size particles and CEC values (Table 4). The correlation between the exchangeable K and organic matter was positively significant ($r = 0.62^{**}$), whereas there was no significant relation between the exchangeable K and the amounts of clay size particles (r = 0. 23) (Table 4). The fluctuating pH levels, from slightly acid (5.12) to slightly basic (7.94), had no direct effect on the potassium potentials of the soils (the correlation coefficient for exchangeable K is r = 0.06). However, the presence of illite in the clay fraction of the soils may also be responsible for K - retention, particularly in the Güzelkonak series with high illite of contents. The high correlation coefficient ($r = 0.93^{***}$) between non-exchangeable and exchangeable K indicates the usual parallel relation between the 2 (Figure 1).

The sum of non-exchangeable K of all the soils studied, except for the Bw1 horizon of the Yuva series and the Ap horizon of the Orak series, is higher than their exchangeable K levels. This is most probably due to the longstanding, historical cultivation of the soils/horizons mentioned above inducing weathering of illite, which has consequently increased the amount of exchangeable K (Özbek et al., 1979; Singer, 1989).

The upper horizons of the soils are grouped into the 4 index groups (Table 3) determined by Cooke (1982) (Table 5) according to their exchangeable K contents. The exchangeable potassium levels for Hasbey II (Group 6), Yuva, Yemişlik II, Orak and İskele (Group 4) and Yemişlik,

Table 3. Non-exchangeable, exchangeable K and K index groups of the soils.

		Successive Extractions of Non-Ex. K (mg 100 g^{-1})								
Horizon	Depth	1	2	3	4	5	6	Sum	Ex. K (mg 100 g^{-1})	Ex. K-Index group
Hasbey Series (Typic Haploxeroll)										
Ap	0-12	8.9	7.6	7.4	4.1	2.7	2.0	32.7	22.6	3
A2	12-30	8.6	8.7	7.6	4.1	2.2	2.4	33.6	20.9	3
Bw1	30-55	7.2	7.2	8.6	2.8	2.2	2.0	30.0	17.1	2
Bw2	55-85	6.7	7.7	10.2	3.1	2.3	2.1	32.1	16.8	2
C	85+	7.7	7.3	6.1	2.6	2.0	1.7	27.4	17.5	2
Hasbey II Series (Typic Haploxeroll)										
Ap	0-12	27.9	24.2	18.8	4.8	4.8	3.5	84.0	84.0	6
A2	12-30	16.7	15.5	12.6	4.9	4.6	2.1	56.4	54.0	5
Bw1	30-55	14.2	13.0	8.9	3.8	3.4	2.1	45.4	28.0	3
Hasbey III Series (Typic Haploxeroll)										
Ap	0-15	8.1	7.8	9.6	3.9	2.9	1.8	34.1	30.4	3
A2	15-30	8.3	8.3	9.5	3.6	2.4	2.4	34.5	26.0	3
Bw1	30-44	7.5	6.8	9.2	3.6	2.9	2.1	32.1	26.3	3
Yuva Series (Calcic Haploxeroll)										
Ap	0-11	12.7	3.1	13.0	3.9	3.5	3.2	49.4	44.2	4
Bw1	11-30	10.6	10.7	12.4	4.4	3.2	2.2	43.5	52.0	5
Bwk2	30-42	5.2	7.4	8.3	2.3	2.3	1.9	27.4	22.6	3
Bw3	42-63	4.7	5.6	7.4	2.6	1.8	1.6	23.7	21.6	3
C1	63-77	5.2	5.4	3.8	2.9	2.1	1.3	20.7	8.9	1
C2	77+	4.7	4.5	5.4	2.2	1.8	1.5	20.1	12.6	2
Yemislik Series (Vertic Xerofluvent)										
Ap	0-17	6.9	7.5	7.5	2.5	2.1	1.4	27.9	25.0	3
Ad	17-35	5.2	4.9	5.8	2.6	1.8	1.3	21.6	15.3	2
A3	35-54	5.1	4.4	5.2	2.6	1.9	1.6	20.8	14.0	2
AC	54-78	5.0	4.1	6.7	2.9	1.7	1.3	21.7	18.3	2
C	78+	5.9	4.3	7.0	3.2	2.2	1.8	24.4	20.2	3
Yemislik Series II (Vertic Xerofluvent)										
Ap	0-16	9.6	6.2	7.7	2.7	1.6	1.8	29.6	41.2	4
Ad	16-34	6.8	4.4	6.2	2.5	1.5	1.2	22.6	25.0	3
A3	34-57	5.0	2.7	5.1	2.5	1.4	1.4	18.1	13.7	2
Orak Series (Calcic Haploxeroll)										
Ap	0-14	13.1	13.3	8.8	3.9	1.9	2.4	43.4	45.2	4
Bw	14-30	11.3	9.9	6.2	3.3	2.2	2.4	35.3	31.2	3
Bwk2	30-46	8.0	7.5	5.8	2.8	1.6	2.4	28.1	21.3	3
Ck	46-70	7.7	6.9	4.8	2.4	1.6	2.0	25.4	20.0	2
Ck2	70+	6.5	4.5	3.6	1.9	1.3	1.5	19.3	12.5	2
Guzelkonak Series (Typic Haploxeroll)										
Ap	0-12	10.0	8.5	5.8	3.1	1.9	2.1	31.4	25.0	3
Ad	12-31	9.2	8.1	5.9	2.8	1.8	2.0	29.8	25.0	3
A3	31-57	7.1	7.1	4.5	2.7	1.6	1.9	24.9	13.0	2
A4	57-86	6.1	5.4	4.0	2.5	1.5	1.5	21.0	12.0	2
Guzelkonak Series II (Typic Haploxeroll)										
Ap	0-15	10.7	8.9	6.4	3.7	2.7	2.1	34.5	26.0	3
Ad	15-35	8.2	7.4	5.5	3.1	2.4	2.1	28.7	16.3	2
A3	35-60	6.1	7.0	4.6	3.4	2.0	1.4	24.5	11.3	2
Iskele Series (Lithic Xerorthent)										
Ap	0-13	14.8	8.6	8.9	4.4	2.3	2.0	41.0	40.0	4
Mülk Series (Typic Xerorthent)										
A1	0-13	7.2	4.1	3.4	1.5	1.2	1.0	18.4	10.9	2
A2	13-25	6.8	3.7	3.0	1.3	1.3	1.0	17.1	7.8	1

Table 4. Some correlation coefficients between soil properties and K values.

Soil K forms	Organic matter	pH	Sand	Silt	Clay	Non-exchangeable K
Exchangeable K	0.62**	0.06	-0.15	-0.13	0.23	0.93***

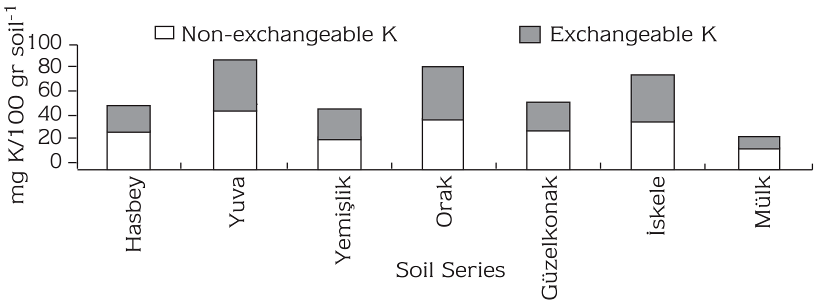

Figure 1. Levels of the non-exchangeable K and exchangeable K in soil series of the Gevaş region

Table 5. The evaluation of exchangeable K index groups (Cooke, 1982).

Index Groups	Exchangeable-K (mg kg^{-1} soil)	K* Kg ha^{-1}	Comments
0	0-50	0-120	K Deficiency symptoms on field without K fertilization
1	51-100	121-240	Greenhouse plants do not show well development without fertilisation
2	101-200	241-480	
3	201-333	481-800	
4	334-500	801-1200	
5	501-750	1201-1800	The use of K fertilizer may be reduced even for potato and vegetables or minimum use
6	751-1250	1801-3000	
7	1251-2000	3001-4800	No need for fertilization of greenhouse plants
8	2001-3000	4801-7200	Reduction of yield due excess levels of K
9	> 3000	> 7200	

* Assuming the presence of 240 t of soil at 20 cm depth in 0.1 ha.

Hasbey, Hasbey III, Güzelkonak, Güzelkonak II (Group 3) are determined to be sufficient for the present non-intensive agriculture, but for the Mülk soils (Group 2) there is a need for K fertilisation.

Discussion

Results indicate that the potassium potential of the studied soils, regarding their K -index groups (Cooke, 1982), for both non-exchangeable and exchangeable, is sufficient for current agricultural practices, namely for the widespread cereal and sugar beet production in the area. A significant correlation between the organic matter and the exchangeable potassium of the soils was determined as earlier stated by Mengel and Kirkby (2001). The contribution of illite to the K - status of the soils studied has been difficult to determine due to its similar contents throughout the profiles. Moreover, even the higher illite of contents seem not to have contributed much to the K - status of the Guzelkonak soils containing the lowest amounts of potential and available K.

Conclusion

A significant correlation between the organic matter and the exchangeable potassium of the soils was determined as earlier stated by Mengel and Kirkby (2001). The contribution of illite to the K - status of the soils studied has been difficult to determine due to its uniform distribution throughout the profiles. Moreover, even the higher contents of illite seem not to have contributed much to the K - status of the Güzelkonak soils containing the lowest amounts of potential and available K. However, results indicate that the potassium potential of the studied soils, regarding their K -index groups (Cooke, 1982), for both non-exchangeable and exchangeable, is sufficient for the current agricultural practices except the soils of the Mülk series. Thus, this would mean a considerable relief to the low – income farmers of the area, partly relying on the subsidies provided by formal bodies, for the K fertilization of the non-intensive production of cereals and particularly of sugar beet.

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