Macromineral Content of Wild Plant Species Grown on Abandoned Cultivated Lands in the Chugoku Region of Western Japan

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Macromineral Content of Wild Plant Species Grown on Abandoned Cultivated Lands in the Chugoku Region of Western Japan

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Contents

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Ⅰ Introduction

The area of abandoned cultivated land in Japan has been increasing every year. In 2010, it increased to 4,000 km^2, while the area of land still under cultivation was 45,930 km^2. The national and local governments of Japan are promoting the re-utilization of abandoned lands. For example, the use of such land for cattle (mainly beef cows) grazing is promoted, and this practice has become widespread, mainly in western Japan.

To ensure that grazing animals are given nutritious fodder, it is important to understand the herbage mass and feeding values of plants grown on grazing land. Previously, we had proposed that herbage mass on abandoned lands should be estimated using community height[14]. Further, we determined the feeding value in terms of total digestible nutrients (TDN) and crude protein (CP) in wild plant communities, including those grown on abandoned lands[13]. Minerals are the main elements contained in the bone and teeth of animals, and are involved in functions such the synthesis of proteins and lipids, and the activation of enzymes; therefore, they are considered to be key nutrients after carbohydrates and proteins[6]. The species composition of vegetation grown on abandoned lands varies considerably according to land use history, length of time since abandonment, and geographical location[3,5,11-13,15]. Hence, plant nutritional value parameters, including the mineral content of grazing herbage may vary greatly from place to place. Data for the mineral contents of wild plant species growing in Japan is scarce. The Standard Tables of Feed Composition in Japan[7] contains data for the mineral contents of only 12 wild plant species; the data on macrominerals is also insufficient. In addition, several major species found on abandoned lands, such as the tall goldenrod (*Solidago altissima* L., Asteraceae), kudzu [*Pueraria lobata* (Willd.) Ohwi, Fabaceae], and cogongrass [*Imperata cylindrical* (L.) Beauv. var. *koenigii* (Retz.) Derand et Schinz., Gramineae] are not listed.

We analyzed the content of 4 macrominerals (calcium, phosphorus, magnesium and potassium) in wild plants grown on abandoned cultivated lands with various dominant species. Thereafter, we determined the content of the minerals in the major dominant species and in the total vegetation.

Ⅱ Materials and Methods

We studied 23 areas of abandoned cultivated lands throughout the Chugoku region of western Japan where we conducted 51 field surveys and samplings from May to October, 2006－2008. The length of time since abandonment of the study areas ranged between 1 and 15 years. In most of the study areas, the land was used for paddy cultivation before abandonment. We established between two to six 1 or 4 m^2-quadrats during each survey. The herbage growing within each quadrat was harvested at the ground level. Samples were classified as dominant species or a compound sample comprised of other species. Plant material was dried, weighed, and subjected wet digestion. Then, the material was analyzed by atomic absorption spectrometry to evaluate the calcium (Ca), magnesium (Mg) and potassium (K) contents, and analyzed by the molybdenum blue method to evaluate the phosphorus (P) content as a percent dry matter (% DM).

Firstly we evaluated the mineral content of each of the major dominant species. Secondly, we evaluated the mineral contents of the compound samples comprising the vegetation within each quadrat computed from the analyzed values and weight of the samples. The suggested range and maximum tolerable levels for each of the 4 minerals are listed by the National Agriculture and Food Research Organization[6]. By comparing the value that we obtained with the listed values, we estimated whether or not the content of certain

minerals present in the dominant species or total vegetation was appropriate for cattle grazing. Ca and P requirements vary with the variety, growth stage, and sex of the animal. We adopted the values for maintenance of mature beef cows that are generally grazed on abandoned cultivated lands in Japan, and assumed a body weight of 500 kg. The ratio of Ca to P (Ca/P ratio) is also a key indicator mainly for P absorption. For example, the absorption rate of P in the animal body decreases when Ca is oversupplied. A Ca/P ratio between 1.5 and 2 is desirable, while a Ca/P ratio between 1 and 7 is also acceptable, if the P content satisfies the requirement[9]. We evaluated the Ca/P ratio based on these criteria.

Ⅲ Results

1 Contents of 4 macrominerals and Ca/P ratio of the major dominant species

The major dominant species in the study sites were the tall goldenrod, silvergrass (*Miscanthus sinensis* Anderss., Gramineae), mugwort (*Artemisia princeps* Pampan., Asteraceae), cogongrass, barnyardgrass [*Echinochloa crus-galli* (L.) Beauv., Gramineae] and kudzu (listed in order of frequency). The contents of the 4 macrominerals and the Ca/P ratio of these species are listed in Tables 1－5.

The Ca content was in the suggested range (0.24%－2.00% DM) for most samples of tall goldenrod, mugwort and kudzu, although 2 samples of kudzu exceeded the maximum tolerable level (2.00% DM; Table 1). Low Ca content was found in the 3 Gramineae species. Particularly in silvergrass, 17 of 21 samples had a Ca content lower than the suggested range; the average value was also below the requirement.

Table 1 The calcium content of the 6 major dominant species and the total vegetation. The total number of samples per species; average Ca content, the numbers of samples with Ca content below the requirement (<0.24% of the DM), with Ca content within the suggested range (0.24%－2.00%), and with Ca content exceeding the maximum tolerable level (>2.00%) are listed.

Species †	*n*	Average ± SD (% DM)	Less than requirement	Within suggested range ‡	Greater than maximum tolerable
Tall goldenrod	46	0.74 ± 0.13	0	46	0
Mugwort	32	0.72 ± 0.23	0	32	0
Kudzu	21	1.28 ± 0.51	1	18	2
Silvergrass	21	0.20 ± 0.07	17	4	0
Cogongrass	16	0.26 ± 0.06	6	10	0
Barnyardgrass	15	0.36 ± 0.13	4	11	0
Total vegetation	165	0.59 ± 0.24	19	146	0

† Scientific names: *Solidago altissima* L., *Artemisia princeps* Pampan., *Pueraria lobata* (Willd.) Ohwi, *Miscanthus sinensis* Anderss., *Imperata cylindrical* (L.) Beauv. var. *koenigii* (Retz.) Derand et Schinz., and *Echinochloa crus-galli* (L.) Beauv. ‡ These values are for the maintenance of mature beef cows with a body weight of 500 kg.

Most of the values for P content in mugwort and barnyardgrass were in the suggested range (0.25%－1.00% DM). However, the P content, as well as the average P content values of many samples of other species were less than the suggested range (Table 2). None of the dominant species samples exceeded the maximum tolerable level for P content (1.00% DM).

Table 2 The phosphorus content of the 6 major dominant species and the total vegetation. The total number of samples per species; average P content, the numbers of samples with Ca content below the requirement (<0.25% of the DM), with P content within the suggested range (0.25%－1.00%), and with P content exceeding the maximum tolerable level (>1.00%) are listed.

Species †	*n*	Average ± SD (% DM)	Less than requirement	Within suggested range ‡	Greater than maximum tolerable
Tall goldenrod	46	0.25 ± 0.07	29	17	0
Mugwort	32	0.35 ± 0.09	2	30	0
Kudzu	21	0.20 ± 0.05	15	6	0
Silvergrass	21	0.21 ± 0.05	16	5	0
Cogongrass	16	0.23 ± 0.05	10	6	0
Barnyardgrass	15	0.35 ± 0.09	2	13	0
Total vegetation	165	0.29 ± 0.08	65	100	0

† See Table 1 for the scientific names. ‡ These values are for the maintenance of mature beef cows with a body weight of 500 kg.

The Ca/P ratio was above the suggested range in many samples of tall goldenrod and kudzu, and below the suggested range in many samples of the 3 Gramineae species (Table 3). Most of the values for the Ca/P ratio in mugwort were in the suggested range.

Table 3 The ratio of calcium and phosphorus (Ca/P ratio) in the 6 major dominant species and the total vegetation. The total number of samples per species; average Ca/P ratio; and the number of samples with a Ca/P ratio below, within, and above the suggested range.

Species †	*n*	Average ± SD	Less than suggested range ‡	Within suggested range ‡	Greater than suggested range
Tall goldenrod	46	3.29 ± 1.15	0	18	28
Mugwort	32	2.21 ± 1.04	0	30	2
Kudzu	21	6.30 ± 3.84	0	5	16
Silvergrass	21	1.05 ± 0.48	18	2	1
Cogongrass	16	1.16 ± 0.29	12	4	0
Barnyardgrass	15	1.06 ± 0.35	7	8	0
Total vegetation	165	2.15 ± 1.05	40	87	38

† See Table 1 for the scientific names. ‡ 1.5－2.0 and 1.0－7.0 (when P content meets the requirement).

The Mg content of most samples of all species, except barnyardgrass, was in the suggested range (0.05%－0.25% DM; Table 4). The Mg content of most barnyardgrass samples exceeded the suggested range; while it exceeded even the maximum tolerable level (0.40% DM) in 5 of the 15 samples. Low Mg content was not found in any sample of the dominant species.

Table 4 The magnesium content of the 6 major dominant species and the total vegetation. The total number of samples per species; the average Mg content; the numbers of samples with Mg content below the suggested range (<0.05% of the DM), within the suggested range(0.05%－0.25%), above the suggested range but below the maximum tolerable level (0.25%－0.40%), and exceeding the maximum tolerable level (>0.40%) are listed.

Species †	*n*	Average ± SD (% DM)	Less than suggested range	Within suggested range	Greater than suggested range and less than maximum tolerable	Greater than maximum tolerable
Tall goldenrod	46	0.16 ± 0.04	0	46	0	0
Mugwort	32	0.18 ± 0.05	0	31	1	0
Kudzu	21	0.22 ± 0.07	0	17	4	0
Silvergrass	21	0.12 ± 0.03	0	21	0	0
Cogongrass	16	0.09 ± 0.02	0	16	0	0
Barnyardgrass	15	0.37 ± 0.11	0	3	7	5
Total vegetation	165	0.18 ± 0.05	0	141	23	1

† See Table 1 for the scientific names.

The K content of all the samples other than those of silvergrass exceeded the suggested range (0.50%－0.70% DM; Table 5). The K content of most of the samples of silvergrass also exceeded the suggested range. Moreover, the K content of many samples of tall goldenrod, mugwort and barnyardgrass exceeded even the maximum tolerable level (3.00% DM).

Table 5 The potassium content of the 6 major dominant species and the total vegetation. The total number of samples per species; the average K content; the numbers of samples with K content below the suggested range (<0.50% of the DM), within the suggested range (0.50%－0.70%), above the suggested range but below the maximum tolerable level (0.70%－3.00%), and exceeding the maximum tolerable level (>3.00%) are listed.

Species †	*n*	Average ± SD (% DM)	Less than suggested range	Within suggested range	Greater than suggested range and less than maximum tolerable	Greater than maximum tolerable
Tall goldenrod	46	2.31 ± 0.66	0	0	39	7
Mugwort	32	2.97 ± 0.66	0	0	20	12
Kudzu	21	1.68 ± 0.44	0	0	21	0
Silvergrass	21	1.44 ± 0.68	1	2	17	1
Cogongrass	16	1.16 ± 0.28	0	0	16	0
Barnyardgrass	15	2.62 ± 0.97	0	0	9	6
Total vegetation	165	1.93 ± 0.56	1	2	152	10

† See Table 1 for the scientific names.

2 Contents of 4 macrominerals and the Ca/P ratio of total vegetation

Figure 1 shows the relationships between the content of each of the 4 macrominerals in the total vegetation and its dominant species. All the relationships were significant ($P < 0.001$), and the coefficients of correlation (R) were 0.795 (Ca), 0.888 (P), 0.893 (Mg) and 0.861 (K).

Tables 1-5 list the contents of the 4 macrominerals and the Ca/P ratio of the total vegetation.

Ca content of the total vegetation in 88% of the quadrats was in the suggested range, while in the other quadrats it was less than the suggested range (Table 1). Of the 19 quadrats where the Ca content was less than the suggested range, 13 quadrats were dominated by silvergrass, and 5 quadrats by other Gramineae

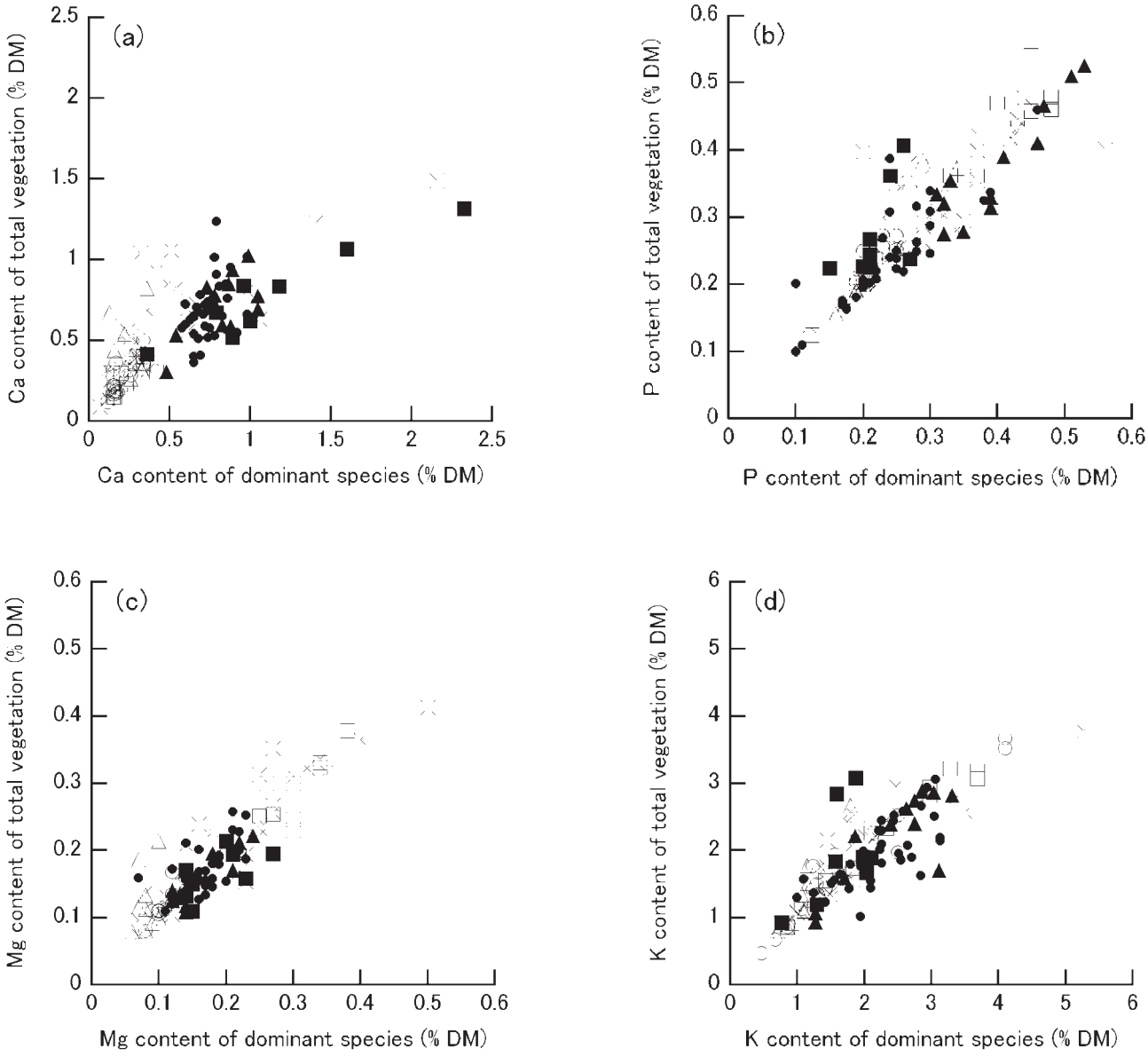

Fig. 1 Relationships in contents of 4 minerals between the total vegetation and the dominant species: (a) calcium (R = 0.795, $P < 0.001$), (b) phosphorus (R = 0.888, $P < 0.001$), (c) magnesium (R = 0.893, $P < 0.001$) and (d) potassium (R = 0.861, $P < 0.001$). The same symbol indicates the same dominant species as follows (see Table 1 for the scientific names).

●: Tall goldenrod
▲: Mugwort
■: Kudzu
○: Silvergrass
△: Cogongrass
□: Barnyardgrass
×: Other species

species.

The P content of total vegetation in 61% of the quadrats was within the suggested range, and in the other quadrats was less than the suggested range (Table 2). The P content was higher than the requirement in most quadrats dominated by mugwort and barnyardgrass, while it was lower than the requirement in many quadrats dominated by other species.

The Ca/P ratio was lower than the suggested range in 24% of the quadrats, and higher in 23% of the quadrats (Table 3). Of the 40 quadrats with a Ca/P ratio lower than the suggested range, 37 were dominated by silvergrass (17 quadrats), barnyardgrass (10 quadrats) or other plants of Gramineae family (10 quadrats). Of the 38 quadrats with a Ca/P ratio above the suggested range, 33 were dominated by tall goldenrod (27 quadrats) or other dicotyledonous species (6 quadrats).

The Mg content of the total vegetation in 85% of the quadrats was within the suggested range, while the other quadrats were above the suggested range (Table 4). The quadrats where the Mg content was greater than the suggested range were dominated most frequently by barnyardgrass (5 of 21 quadrats) but also by other various plants. The Mg content of the total vegetation in only 1 quadrat exceeded the maximum tolerable level, dominated by *Polygonum thunbergii* (Siebold et Zucc.) H.Gross var. *thunbergii* (Polygonaceae).

The K content of the total vegetation in 98% of the quadrats was more than the suggested range and in 6% of the quadrats was more than the maximum tolerable level (Table 5). In the quadrats where K content exceeded the maximum tolerable level they were dominated by various plants belonging to different taxonomic groups.

Ⅳ Discussion

The contents of macrominerals may differ with land-use history, parent materials of soils, and growing stage or season, even among samples from the same species. It is difficult to determine how each of these factors affects the macromineral contents on the basis of our data. Much more data is required for this purpose; our aim is to collect considerable data in the future. On the other hand, the composition of wild plants grown on an abandoned cultivated land reflects land use history and soil properties[4]. Additionally, the contents of the 4 macrominerals in the total vegetation could be largely accounted for by plants of the dominant species (Fig. 1). These findings suggest that the mineral content of total vegetation can be estimated on the basis of the dominant species, and that a strategy for managing an excess or deficiency of these minerals can be developed.

The Ca content of the total vegetation was mostly in the suggested range, and it never exceeded the maximum tolerable level (Table 1). However, silvergrass and its dominant vegetation were often found to have insufficient Ca. Generally, Ca content of Gramineae species was less than that of other taxa[7]. The National Agriculture and Food Research Organization[7] reported that the Ca content of silvergrass in Japan was 0.23% DM (0.20% DM was the average value according to our data), having the lowest Ca value of all wild plant species. Ca deficiency leads to failure to form new bone and retarded growth in young animals, and osteoporosis and osteomalacia in older animals[9]. Therefore, for cattle grazing on vegetation dominated by silvergrass and other Gramineae species, Ca should be added with mineral salt or herbage legumes such as alfalfa instead of grains, which also have low Ca content[9].

The P content was low in 39% of the total vegetation samples that were dominated by various species, especially tall goldenrod, kudzu, silvergrass and cogongrass (Table 2). This may have been because of the

low availability of phosphoric acid, which is a characteristics of Japanese soil[1]. The National Agriculture and Food Research Organization[7] reported that the P content of silvergrass was 0.10% DM, which was less than our estimation of the average value. P deficiency leads to inappetence, poor lactating performance, and low fertility in adults, and unthriftiness and poor growth in younger animals[9]. Hence, P supplements such as wheat bran and rice bran[6] are required for cattle grazing on vegetation dominated by tall goldenrod, kudzu, silvergrass and cogongrass.

A balance of Ca and P is important for the efficient absorption of these minerals. The Ca/P ratio of the total vegetation was less than the suggested range in 24% of the quadrats, and greater than the suggested range in 23% of the quadrats (Table 3). Since this was caused by either a low level of Ca or P, as mentioned above, supplements should be added to the animal's diet.

The Mg content of the total vegetation in 85% of the quadrats was in the suggested range (Table 4). On the other hand, most of the values for the total vegetation indicated an excess of K content (Table 5). While a deficiency of Mg leads to grass tetany, an excess of K prevents the absorption of Mg in the animal body[8]. In an experiment by Newton *et al.*[10], it was found that lambs fed on a high K diet (4.90% DM) had a 50% reduction in apparent Mg absorption as compared to lambs fed on a low K diet (0.60% DM). The Mg content of the total vegetation was more than 0.10% DM (double the value of the minimum tolerable level of Mg content) for most data. Although the Mg content of the vegetation dominated by cogongrass had a value lower than 0.10% DM, its K content did not exceed the maximum tolerable level (3.00% DM). Therefore it was concluded that the incidence of grass tetany may be low in cattle grazing on abandoned cultivated lands.

An excess of K causes cardiac insufficiency[2]. The K content of the total vegetation in 6% of the quadrats was more than the maximum tolerable level (Table 5). It is difficult to determine from the dominant species whether the K content exceeded the maximum tolerable level; hence, this should be deduced from the land-use history of the area in question.

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Summary

While cattle (mainly beef cows) grazing on abandoned cultivated land has become widespread in Japan, there is insufficient data on the mineral content of the wild plant species growing there. We analyzed the content of 4 macrominerals, namely calcium (Ca), phosphorus (P), magnesium (Mg) and potassium (K) in the wild plant species grown on abandoned cultivated lands with various dominant species. Further, we determined the content of these minerals in the major dominant species and total vegetation. The major dominant species in the study sites were the tall goldenrod (*Solidago altissima* L.), silvergrass (*Miscanthus sinensis* Anderss.), mugwort (*Artemisia princeps* Pampan.), cogongrass [*Imperata cylindrical* (L.) Beauv. var. *koenigii* (Retz.) Derand et Schinz.], barnyardgrass [*Echinochloa crus-galli* (L.) Beauv.] and kudzu [*Pueraria lobata* (Willd.) Ohwi] (listed in order of frequency). The content of the macrominerals in the total vegetation could mostly be accounted for by the dominant species. The Ca content of the total vegetation was mostly in the suggested range, and it never exceeded the maximum tolerable level. However, silvergrass and its dominant vegetation were often Ca deficient. Low P content was found in 39% of the total vegetation that was dominated by various species, especially tall goldenrod, kudzu, silvergrass and cogongrass. The Ca/P ratio of the total vegetation was less than the suggested range in 24% of the quadrats, and greater than the suggested range in 23% of the quadrats. The Mg content of the total vegetation was within the suggested range in 85% of the quadrats. It was concluded that the incidence of grass tetany was low in cattle grazing on abandoned cultivated lands. However, most of the data on the total vegetation indicated an excess of K; in 6% of the quadrats the value exceeded the maximum tolerable level. It is difficult to determine whether the K content is appropriate for grazing on the basis of the dominant species.

中国地方の耕作放棄地における野草の主要ミネラル含量

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摘　　要

耕作放棄地における牛（主に肉用種繁殖牛）の放牧がわが国各地に広がっている一方で，その際に採食される野草のミネラル含量に関するデータは十分でない．本研究では，中国地方の耕作放棄地に生育する野草の主要な4種のミネラル（カルシウム，リン，マグネシウムおよびカリウム）を分析し，優占種と群落全体のミネラル含量を明らかにした．調査地の主な優占種は出現頻度の順に，セイタカアワダチソウ，ススキ，ヨモギ，チガヤ，イヌビエおよびクズであった．群落全体のミネラル含量は優占種のミネラル含量と類似していた．群落全体のカルシウム含量はほとんどが適正範囲内にあり，許容摂取限界を超えることはなかった．しかしながら，ススキおよびススキの優占する群落ではカルシウム含量の不足が散見された．群落全体のリン含量は全データの39%で不足しており，その場合の優占種はさまざまであった．特にセイタカアワダチソウ，クズ，ススキおよびチガヤで不足が著しかった．群落全体におけるカルシウムとリンの比率では，全データの23%が適正範囲を下回り，24%が適正範囲を上回った．群落全体のマグネシウム含量では，全データの85%が適正範囲内にあり，それを下回ることはなかった．耕作放棄地における放牧牛のグラステタニー発生の可能性は，優占種のいかんに関わらず低いものと考えられた．一方，群落全体のカリウム含量はほとんどが過剰状態にあり，全データの6%で許容摂取限界を超えていた．カリウム含量が適正範囲にあるかどうかを優占種から決定することは困難であった．

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