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The Energy Flow and Mineral Cycles in a *Zoysia japonica* and a *Miscanthus sinensis* Ecosystem on Mt. Kwanak 6. The Cycles of Ca, Mg, Na

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관악산의 잔디와 억새 생태계에 있어서 에너지의 흐름과 무기물의 순환 6. Ca, Mg, Na의 순환

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ABSTRACT

To find out the mineral cycles of calcium, magnesium and sodium in dynamic grassland ecosystems in a steady state condition, this investigation was conducted along the northwest side on Mt. Kwanak. The experimental results may be summarized on the communities of a *Zoysia japonica* and a *Miscanthus sinensis* as follows.

As compared with some properties of the surface soils among two semi-natural grasslands, calcium (Ca) was greater quantity in a *Zoysia japonica*, whereas, in a *Miscanthus sinensis*, sodium (Na) and magnesium (Mg) were greater in Mt. Kwanak.

For the case of steady production and release, the ratio of annual mineral production to the amount accumulated on the top of mineral soil in a steady state provides the estimates of release constant k. The release constants of Ca, Mg and Na of the litter were 0.42, 0.25 and 0.29 in the *Zoysia japonica* grassland, and were 0.41, 0.54 and 0.62 in the *Miscanthus sinensis* grassland, respectively. The half times of Ca, Mg and Na required for the release or accumulation of the litter on the grassland were 1.65, 2.77 and 2.39 in the *Zoysia japonica*, and were 1.69, 1.28 and 1.12 in the *Miscanthus sinensis*, respectively. The increasing order of the turnover parameters of the elements was Ca, Na and Mg in the *Zoysia japonica* grassland, and was Na, Mg and Ca in the *Miscanthus sinensis* grassland.

The amounts of annual cycles for Ca, Mg, Na in the grassland ecosystem under the steady-state conditions were 1.29, 0.20 and 0.12 g/m^2 in the *Zoysia japonica* grassland and 3.91, 1.04 and 0.61 g/m^2 in the *Miscanthus sinensis* grassland.

Key words: *Zoysia japonica, Miscanthus sinensis,* Mt. Kwanak, Calcium, Magnesium, Sodium, Mineral cycles.

INTRODUCTION

Inorganic environmental chemical elements are becoming more and more important for scientific research. In the last two decades a trace element has changed its status from being inessential to being essential for living systems approximately every two years, formly nontoxic elements attained the status of potentially toxic, and a large proportion of the analytical results obtained for various biomaterials are mainly intended to demonstrate the powerful capabilities of the newly emerging investigation (Markert and Thornton, 1990).

The soil of grassland is a complex system which has many processes taking place simultaneously and which might properly be interpreted in terms of nutrient chemistry, microbial transformations of organic matter, mineral weathering and others. Plant communities alter the organic and inorganic reactions in soils through cycling processes and are in turn altered by such changes (Oohara *et al.*, 1971a). Chemical elements that cycle through living organisms which are constructed from these chemical elements, and one way to building out an ecosystem is to follow the transfer of element between the living and the nonliving worlds.

Some chemical elements can play an essential role in the normal growth and development of an organism (Bratter and Schramel, 1988; Fiedler and Rosler, 1988; Marschner, 1986). These elements have achieved the status of essentiality and according to their physiological functions they can act on structural and enzymatic elements in living organisms.

Chemical elements cycle within the biospere, but energy flows one way. They may be accumulated with successive searal. stages. It is compartmentalized, occurring in soil and rocks, in soil solution, in atmosphere, and in biomass. Biotic chemical factors include decomposition, root exudation, and retrieval of deeplying nutrients (Begon, Harper and Townsend, 1990). Calcium has a physical role in soil and was important in flocculating clay particles. Certain types of soils have significant amounts of calcium phosphate or sulphate and many contain calcium in feldspars, amphibolites and various clay minerals (Likens *et al.*, 1977). In very acid soils, however, the levels may be low enough to induce deficiencies in plants. Magnesium was present in many primary silicate minerals and particularly associated with clays. It was a major nutrient and was associated with activating physiological enzyme activating systems, and an essential as a constituent of the chlorophylls of litters. Sodium was present in certain silicate minerals such as feldspars and amphibolites.

The soil provides a large storage compartment in the ecosystems of grassland. The exchange sites are saturated with cations, and rainfall-flow discharge maintains a constant chemical concentration for major chemical elements (Waring and Schlesinger, 1985).

Simple dissociation of minerals in water also makes nutrients available from rock and soil and so do hydrolytic reactions involving organic acids released from grass roots, fungi or lichens (Ascaso *et al.*, 1982). A particular nutrient minerals may be taken up by a grass that is eaten by a herbivore that dies and is decomposed, releasing the element back to the soil from where it is taken up through the roots of another grassland. In most every case, the inputs and outputs of nutrients are small in comparison with the amounts held in biomass and recycled within the system (Lindberg *et al.*, 1986).

Productivity and nutrient cycling do not differ greatly in ecosystems that are not disturbed (Jordan and Herrera, 1981). The important assesment of the nutrient cycle in ecosystem must consider the role of the litter, decomposing as it affects the structure of the grassland. Koelling and Kucera (1965) have shown that for any complete assessment of such a cycle, leaching of several elements takes place at least from standing dead vegetation. According to Oohara *et al.* (1971 a, b, c, d, e) and Chang *et al.* (1995a, b, c, d, e), there is the role of the mineralization, accumulation and annual cycles of mineral elements in the grassland ecosystems in a steady state condition. While it may not be directly applicable to agricultural ecosystems, it is valuable since it suggests testable inferences concerning more complex systems.

In the present study, the chemical composition of mineral components in litters under the dynamic ecosystems of grasslands has been determined to assess the levels of nutrients in such litter. Furthermore, the cycles of mineral components in the grasslands of *Zoysia japonica* and *Miscanthus sinensis* were estimated and compared. It was the intent of the present study to gain information concerning the role of the cycles of mineral components in the functions of the grassland ecosystems.

MATERIALS AND METHODS

The studied area and the methods to prepare the litter samples of *Zoysia japonica* and *Miscanthus sinensis* for mineral components were analyzed by Chang *et al.* (1995a, b) and measured according to the method of Allen *et al.* (1974). The litter samples were collected by the quadrat method from the L, F, H and A_1 horizon in the *Zoysia japonica* and *Miscanthus sinensis* grasslands in Mt. Kwanak. The litter production was estimated in the condition of dry weight. Mineral elements were measured as the difference between the inorganic element from comparable ignited at 550℃ and unignited samples. Each elements of these extracts were determined by the flame photometry and an atomic absorption spectrophotometer (Model 303). Calcium was measured at 422.7 nm wavelength and adjust airs and gas flows, slit width and other settings as recommended for this instrument. Mg and Na were the same as the prescribed method of calcium. These elements were measured at 285.2 and 589.0 nm wavelength, respectively.

RESULTS AND DISCUSSION

1. Mineral elements (Ca, Mg and Na) of the soils in Mt. Kwanak

Mineral elements (Ca, Mg, Na) of the surface soils for the grasslands of *Zoysia japonica* and *Miscanthus sinensis* were given in Table 1. It indicates that the quantitative levels of each mineral component in *Miscanthus sinensis* grassland were higher than those in *Zoysia japonica* grassland.

The content of calcium in chalk and limestone soils may be more than 30%. In most non-calcareous soils the forms of calcium were more variable but it was still an important soil element. Certain types of soils have significant amounts of calcium phosphate or sulphate and many contain calcium in feldspars, amphibolites and various clay minerals. In very acid soils, however, the levels may be low enough to induce deficiencies in plants. Calcium has a physical role in soil and was important in flocculating clay particles. In Mt. Kwanak, the annual production of calcium for litters of the *Zoysia japonica* and *Miscanthus sinensis* grasslands were 1.296 and 3.917 g/m^2, respectively.

Magnesium was present in many primary silicate minerals and also occurred in dolomite and certain salts. It was widely distributed in soils and was particularly associated with clays. In general, availability was higher in basic and neutral soils and lower in acid soils where a deficiency may occur. It was now accepted as being a major nutrient and was needed by all organisms since it activated many exoenzyme systems and was involved in phosphorus transfer processes. It was an essential as a constituent of the chlorophylls of litters. In our data of Mg investigated in Mt. Kwanak, the annual production for litters of the *Zoysia japonica* and *Miscanthus sinensis* grasslands were 0.201 and 1.046 g/m^2, repectively.

Although sodium was present in certain silicate minerals such as feldspars and amphibolites, the levels in non-saline soils were relatively low. There was some interest in the extractable sodium content of soils because of its inclusion in the total extractable

Table 1. The amount of calcium, magnesium and sodium for the accumulation and the decomposition of litters from *Zoysia japonica* and *Miscanthus sinensis* grasslands on Mt. Kwanak

Grasslands	Horizon	Calcium	Magnesium	Sodium
			(g/m^2)	
	L	1.296±0.034	0.201±0.008	0.122±0.033
Zoysia japonica	F	0.621±0.024	0.157±0.004	0.085±0.001
	H	0.477±0.018	0.067±0.001	0.045±0.001
	A_1	0.706±0.029	0.366±0.008	0.174±0.003
	L	3.917±0.097	1.046±0.026	0.613±0.018
Miscanthus sinensis	F	3.332±0.086	0.546±0.014	0.195±0.007
	H	1.917±0.054	0.234±0.008	0.120±0.012
	A_1	0.404±0.010	0.123±0.003	0.065±0.001

Table 2. The amount of calcium, magnesium and sodium from *Miscanthus sinensis* grassland on Mt. Kwanak

Fractions	Calcium	Magnesium	Sodium
		(g/m^2)	
Live-stem	0.885±0.151	0.399±0.082	0.178±0.004
Dead-stem	0.280±0.016	0.060±0.002	0.058±0.003
Live-leaves	2.075±0.378	0.508±0.124	0.284±0.014
Dead-leaves	0.677±0.542	0.079±0.006	0.093±0.006

base summation. In the case of Na, the annual production for litters of the *Zoysia japonica* and *Miscanthus sinensis* grasslands were 0.122 and 0.613 g/m^2, respectively. Other detailed characteristics of the litter organic matters for each horizon of surface soils and grass species were shown in Table 1. The cascade flow of mineral components from the soils of *Miscanthus sinensis* grassland in Mt. Kwanak were marked in Table 2. That means that the living leaves was more influenced on their mineral contents, and finally reached to much more releasing and minimizing mineral component, the dead stems.

2. The estimates of release constant of mineral elements (Ca, Mg, Na)

Under the assumption (Oohara *et al.*, 1971 a and e; Chang *et al.*, 1995a, 1995b) that the grassland floors in the stands selected here may approximate a steady state, one method of estimating the release or loss constant k for mineral components of the grass-litter of *Zoysia japonica* and *Miscanthus sinensis* grasslands can be obstained from the ratio of the vertical and horizontal coordinates of each point on Fig. 1 and Fig. 2, respectively. Other methods are also suggested in the previous papers (Oohara *et al.*, 1971 a, b, c, d and e).

The estimates of constants for the *Zoysia japonica* grassland and *Miscanthus sinensis* grassland are given by Table 3. As compared with each grassland, k value was higher in

Table 3. Parameters for the exponential decomposition of calcium, magnesium and sodium from *Zoysia japonica* and *Miscanthus sinensis* grasslands on Mt. Kwanak

Grasslands	Parameters	Calcium	Magnesium	Sodium
			(g/m^2)	
Zoysia japonica	Release constants	k=0.42	k=0.25	k=0.29
	$1/k$	2.38	4.00	3.45
	Half time (years)	1.65	2.77	2.39
	95% time (years)	7.14	12.00	10.35
	99% time (years)	11.90	20.00	17.25
Miscanthus sinensis	Release constants	k=0.41	k=0.54	k=0.62
	$1/k$	2.44	1.85	1.61
	Half time (years)	1.69	1.28	1.12
	95% time (years)	7.32	5.55	4.83
	99% time (years)	12.20	9.25	8.05

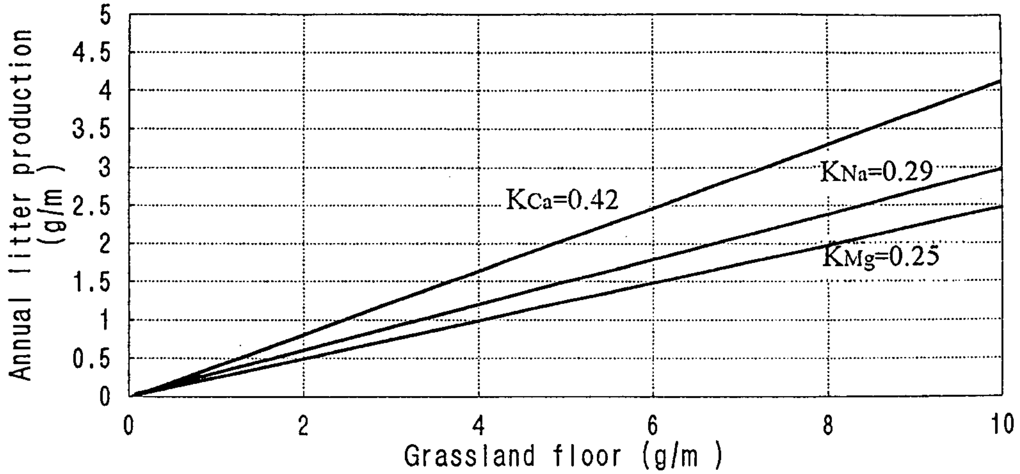

Fig. 1. Estimates of the release constants for mineral components, Ca, Mg, Na in the *Zoysia japonica* grassland from the ratio of annual addition of mineral components to the steady state accumulation of a grassland floor.

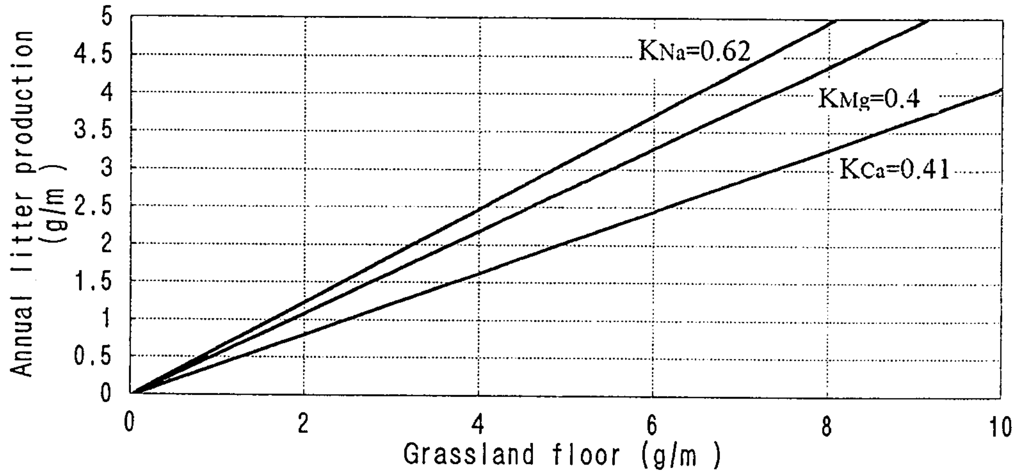

Fig. 2. Estimates of the release constants for mineral components, Ca, Mg, Na in the *Miscanthus sinensis* grassland from the ratio of annual addition of mineral components to the steady state accumulation of a grassland floor.

the *Miscanthus sinensis* grassland, while lower in the *Zoysia japonica* grassland. From these results, it seems reasonable to suggest that the chemical composition of the grass-litter and its annual addition to the mineral soil in a semi-natural grassland ecosystem are diffent on account of the grass species of which the grassland is composed.

The release constant *k* as a fraction of the original total was determined by the assumption of Oohara *et al.* (1971 a, e) and Chang *et al.* (1995a, 1995b). Fig. 1~2 and Table 3 indicated the same tendency of changes for each mineral element and each grassland. These results suggests that the higher the release or loss constant of mineral elements from the litter in the surface soil are, the more rapidly these elements return to the soil. The release constant k of calcium of the litter of *Zoysia japonica* and *Miscanthus sinensis* on Mt. Kwanak were 0.42 and 0.41, respectively. The periods from organic mineral components to 50, 95 and 99% of exchangable mineral components were 1.65, 7.14 and 11. 90 years in the *Zoysia japonica* grassland ecosystem, and 1.69, 7.32 and 12.20 years in the *Miscanthus sinensis* grassland ecosystem.

The release constant k of magnesium and sodium of the litter of *Zoysia japonica* on Mt. Kwanak were 0.25 and 0.29, respectively. The periods from organic mineral components to 50, 95 and 99% of exchangable mineral components were 2.77, 12.00 and 20.00 years in magnesium, and 2.39, 10.35, 17.25 years in sodium, respectively.

In the litter of *Miscanthus sinensis* on Mt. Kwanak, The release constant k of calcium, magnesium and sodium were found out to 2.44, 1.85 and 1.61, respectively. The periods from organic mineral components to 50, 95 and 99% of exchangable mineral components were 1.69, 7.32 and 12.20 years in calcium of the litter, and 1.28, 5.55, 9.25 years in magnesium, and 1.12, 4.83, 8.05 years in sodium, respectively.

3. The mineral elements cycling

Productivity and nutrient cycling do not differ greatly in ecosystems that are not disturbed (Jordan and Herrera, 1981). Since the release constant of mineral components for grass-litters have been determined, the release models of mineral components under the grassland ecosystems of the steady state conditions can be defined as the basic concept of decomposition (Oohara *et al.*, 1971a, e); in the case of mineral components

$$M=M_0e^{-kt} \quad \cdots\cdots (1)$$

where M_0 is the weights of mineral components in the surface initially. The soil provides a large storage compartment in the ecosystems of grassland. As rainfall-flow discharge maintains a constant chemical concentration for major chemical elements, the exchange sites are saturated with cations, Ca, Mg and Na (Waring and Schlesinger, 1985). Table 3 presents exponential equations for the two grasslands at Mt. Kwanak, and Fig. 3 and Fig. 4 show the exponential curves of these models. The accumulation model of mineral components on the grassland floor is also given as follows; for mineral components (M_a)

$$M_a = \frac{L_n}{k}(1-e^{-kt}) \quad \cdots\cdots (2)$$

where L_n expresses the amount of an annual addition for this element. This graphical curve is given as the mirror image of the curve for the release (Fig. 3). In agreement with the results of Ovington and Heitkamp (1960), it has been shown in this paper that a greater quantity of Ca were taken up from the mineral components of soils than that of Mg and Na.

The equation of annual cycles of mineral components in a steady state ecosystem of a grassland are given by using the assumptions of the previous papers Oohara *et al.* (1971, a and e) and Chang *et al.* (1995 a-e). In this study, the applicable models of two grassland ecosystems are shown in Table 3, Fig. 3 and Fig. 4. They indicated the annual cycle of quantitative each minerals. It presented the graphical expression of these equations.

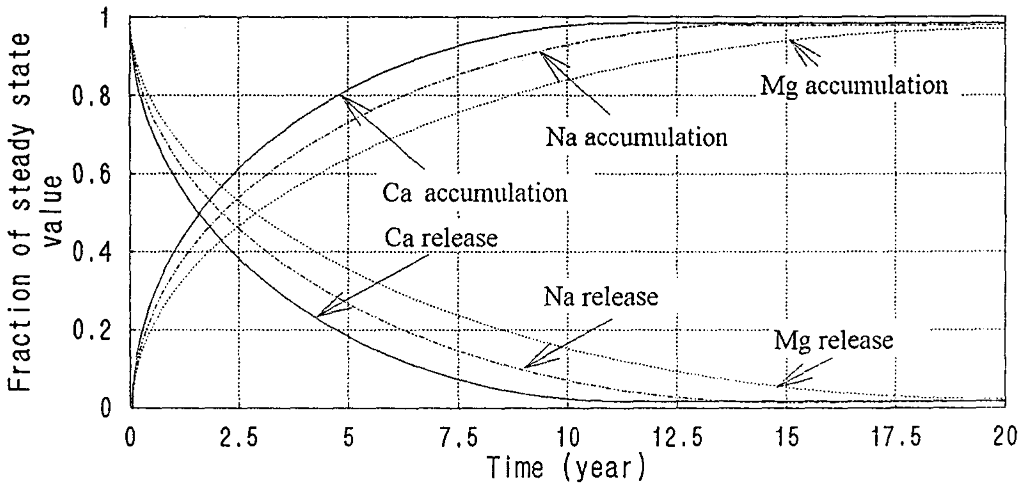

Fig. 3. Relation between the accumulation and decomposition of the mineral components from the litters of the *Zoysia japonica* grassland on Mt. Kwanak.

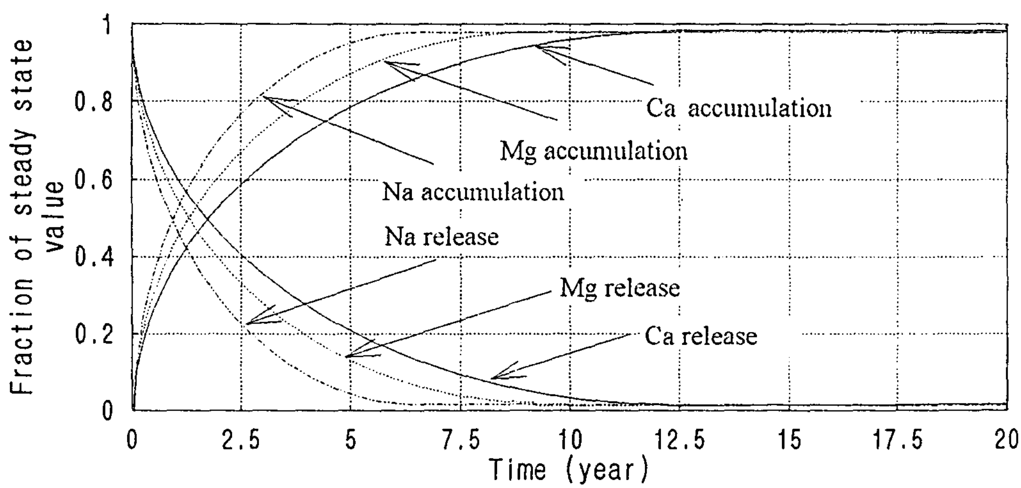

Fig. 4. Relation between the accumulation and decomposition of the mineral components from the litters of the *Miscanthus sinensis* grassland on Mt. Kwanak.

That means that the data differs from the current annual uptake and mean annual uptake (Ovington and Heitkamp, 1960). It can be said that, however, the levels of those may contribute directly to the amounts of the major portion of the current annual uptake or mean annual uptake. Therefore, a shortage of mineral nutrients is hardly ever seen in semi-natural grasslands of a steady state condition but can often be seen in tame pastures. Annually, Management of pastures requires an addition of supply at least the same levels of fertilizers equalling amounts of annual cycles of various mineral nutrients to absorb the mean annual uptake for the steady harvest of forage crops.

Chemical elements may be accumulated with successive searal stages. As biotic chemical factors include decomposition, root exudation, and retrieval of deeplying nutrients (Begon, Harper and Townsend, 1990), the quantitative annual cycles of these elements in the grassland ecosystems of a steady state condition can be estimated by the same principle likewise in this investigation. Those of mineral component, Ca, in the *Zoysia japonica* and *Miscanthus sinensis* grassland were 1.296 and 3.917 g/m^2, respectively. Those of mineral component, Mg, in the *Zoysia japonica* and *Miscanthus sinensis* grassland were 0.201, 1.046 g/m^2, and in Na there were 0.122 and 0.613 g/m^2, respectively. As compared with the grassland of *Phragmites longivalvis* in the delta of the Nakdong river (Chang and Ahn, 1995), the content of Ca in the *Zoysia japonica* and *Miscanthus sinensis* grassland in Mt. Kwanak were generally higher, whereas the quantity of Na from each grassland in Mt. Kwanak were lower than that of *Phragmites longivalvis* grassland in the delta of the Nakdong river. It indicated that the environmental condition of the grassland were partially determined by the grass productivity and adjacent physical environment on each grassland. Although simple dissociation of minerals in water by the action of rain-fall and stream flow which also makes nutrients available from rock and soil and so do hydrolytic reactions involving orgnic acids released from grass roots, fungi or lichens (Ascaso *et al.*, 1982), from the view of ecological dynamic stable status the increasing order of the turnover parameters of the elements have marked to Ca, Na and Mg in the *Zoysia japonica* grassland, and to Na, Mg and Ca in the grassland of *Miscanthus sinensis*.

적 요

본 연구는 유동적인 초지생태계의 칼슘, 마그네슘 및 나트륨의 순환을 관악산의 북서면에 위치하는 잔디와 억새초지를 통해 규명하고자 한 것으로 그 결과는 다음과 같다.

두 개의 초지군락에서 표면층의 토양을 비교해 보면 칼슘, 마그네슘, 나트륨의 함량이 잔디 군락보다는 억새 군락에서 더 높게 함유되어 있음을 알 수 있었다. 잔디군락에서 칼슘, 마그네슘, 나트륨의 release contants는 0.42, 0.25, 0.29로 각각 나타났다. 억새 군락에서는 칼슘, 마그네슘, 나트륨의 release contants가 각각 0.41, 0.54, 0.62로 각각 나타났다.

평형상태에서 50, 95 및 99%로 분해 및 축적되는데 걸리는 시간은 각각 0.693/k, 3/k과 5/k 년이므로, 본 연구를 통하여 관악산의 초지생태계에서 칼슘이 50, 95 및 99%로 분해 및 축적되는데 걸리는 시간은 잔디군락에서는 1.65, 7.14과 11.90년으로 나타났으며 억새군락에서는 1.69,

7.32 및 12.20년으로 각각 나타났다. 마그네슘은 50, 95 및 99%로 분해 및 축적되는데 걸리는 시간은 잔디군락에서는 각각 2.77, 12.00과 20.00년으로 나타났으며 억새군락에서는 1.28, 5.55 및 9.25년으로 나타났다. 나트륨은 50, 95 및 99%로 분해 및 축적되는데 걸리는 시간은 잔디군락에서는 각각 2.39, 10.35과 17.25년으로 나타났으며 억새군락에서는 1.12, 4.83 및 8.05년으로 나타났다.

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