Steppe felt accumulation in *Leymus chinensis* communities of eastern Transbaikalia and transformation of its chemical composition

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Abstract. The study objective is to determine stocks and chemical composition of died phytomass and felt in *Leymus* coenoses in southeastern Transbaikalia. Using standard field geobotanical tools, the authors have determined macroelement composition by generally accepted techniques, calculated indicators of litter-fall index (LFI), C/N, C/P, C:N:S:P, Ca/K ratios. Statistical data processing has been carried out in Microsoft Excel. At present, the felt stock is 54–107 g/m$^2$. Died phytomass content depends on the species composition in the coenoses, soil and environmental conditions of their growth, and the grazing load degree. The coefficient of correlation between died phytomass and felt content shows moderate value. The steppe litter-fall index indicates a low rate of felt decomposition. The felt chemical composition is defined by soil and environmental conditions (supply of nutrients and moisture). For the first time study has revealed that died phytomass and felt are highly resistant to decomposition and mineralization according to C/N, C/P, C:N:S:P and Ca/K ratio values in the aboveground phytomass of coenoses. However, the resistance can be adjusted once the species composition, climatic (drought, heavy rainfall) and anthropogenic conditions (spring burnings and steppe fires) change.

1. Introduction
An integral part of the aboveground phytomass of coenoses is died phytomass and steppe felt availability. The significance of the aboveground fall accumulation for herbaceous communities, including steppe ones, is due to the fact that the seasonal dynamics of their development for each vegetation season period is characterized by a certain combination of growth and dying off of plant green parts, litter accumulation on the soil surface, and further decomposition of dead residues. Ash elements are returned to soil as a result of these processes, and it is enriched with organic substances. The decomposition cycle of plant litter (felt) in meadow steppes, steppe and halophytic meadows average for several years [1, 2].

The similarity of optimal hydrothermal conditions for plant photosynthesized organs and for phytomass decomposing organisms indicates biogeocenotic organization of meadow steppe and steppe meadow landscapes, aimed at retaining organic elements in the soil–plant system.

The aboveground mortmass (died phytomass and felt) accumulation can be the main cause and driving factor of mesophytization autogenous processes [2]. The amount of felt accumulation in different types of
steppe vegetation varies significantly, and is determined by the species composition and precipitation. For example, felt stocks may be 8–10 t/ha in the steppe, forest-steppe and meadows, in moderately arid steppes – 6 t/ha, in dry ones – 3 t/ha [3]. Such high rates are currently possible only under the reserved regime, and in areas with sufficient precipitation.

Due to climate change, the felt stocks have decreased greatly, which is confirmed with the data by E.G. Nechaeva et al. [4]. Thus, the felt accumulation has been 71–87 g/m² in the natural steppe ecosystems of the South Minusinsk depression (southern Central Siberia), 25–44 g/m² – in the Kharanor steppe (southeastern Transbaikalia).

Grazing [5–7] and steppe fires [8] are important factors affecting the felt stocks and its mineralization length. The renewal of the aboveground mortmass natural level after strong grazing load removal can last for years, for example, the accumulation of mortmass took 10 years, from 43–107 to 178–250 g/m² [9] in the dry steppe (Tuva).

Depending on the steppe type, the ratio of felt, died phytomass and green shoots differs. The structure of aboveground phytomass consists of 50 % green shoots, 35 % of died phytomass, and 15 % of felt for typical steppes; and 40–45 % of green shoots, 55–60 % of died phytomass and felt – for meadow steppes [10].

The decomposition rate of dead organic matter of litter and felt (litter-fall index) can be a criterion that determines the stability of biogeocenosis, and allows assessing the qualitative and quantitative indicators of the littilel biological cycle [11–12]. The litter-fall index (LFI) value is determined by the ecosystem type, species biological characteristics, plant matter fraction and its chemical composition, and depends on the soil-environmental conditions of the coenosis habitat. This indicator is not constant and is characteristic only for certain conditions (time of sampling). Both microorganisms, and soil fauna take part in the processes of steppe felt transformation. This is a multi-stage biological process that includes not only decomposition, but the synthesis of complex organic compounds [13]. The main transformation in the chemical composition of plant material occurs in the link ‘green phytomass – died phytomass’. The felt serves an active biogeochemical barrier that traps and re-accumulates biogenic elements. The regularities of the chemical composition transformation in the link of green phytomass – died phytomass – felt are common for grassy ecosystems in general [14].

The seasonal and long-term dynamics of mortmass before aridization [15] and under modern climate conditions [16] have been studied for the steppe communities of eastern Transbaikalia; besides, there are data on the microbiological destruction of plant litterfall in the steppe ecosystems of southeastern Transbaikalia [17]. The presence of steppe felt in steppes with a harsh continental climate is of great importance for the processes of soil upper horizon thermal and water regimes, preservation of renewal buds in winter, as the soils freeze up to 3–4 m depth. There is no data on the accumulation of died phytomass, felt and their chemical composition in southeastern Transbaikalia. This necessitates a comprehensive study of these indicators in leymus coenoses growing under different soil and environmental conditions. The research objective is to determine the stocks and chemical composition of died phytomass and felt in Leymus coenoses in southeastern Transbaikalia.

2. Materials and Methods
Field research was carried out in 2019 in the steppe zone of Transbaikal Region. The study object was monodominant leymus coenoses (Leymus chinensis (Trin.) Tzvel.), which grew on different soil types (table 1), and functioned in the haloxerophytic steppe (Description 1), dry steppe (Descriptions 2, 3), floodplain steppe meadows ( Descriptions 4, 5, 6).

The selection of study areas resulted from vast areas of grassy ecosystems: hayfields make up 98,973 ha, pastures – 247,608 ha in the Olovyannin District; 55,746 and 326,467 ha – in the Agin District, respectively. Mean multiyear precipitation at the studied areas is 325 mm, and 306 mm – for the growing season
according to the Agin weather station. At the studied period, the total precipitation for May-September was 309 mm. This is not typical for the steppe territories of southeastern Transbaikalia (table 2).

### Table 1. Leymus coenoses of eastern Transbaikalia.

| Number of descriptions, soil | Geographic coordinates | Total projective cover, % | Leymus projective cover, % | Number of species | Co-dominants |
|-----------------------------|------------------------|---------------------------|----------------------------|------------------|--------------|
| 1, typical saline           | N50.9363° E115.4190°  | 80                        | 55                         | 19               | *Artemisia anetofila* Web. ex Stechm. |
| 2, lithosol light-humus     | N50.8646° E115.4614°  | 90                        | 70                         | 16               | *Carex duriuscula* C.A. Meyer |
| 3, lithosol light-humus     | N50.8643° E115.4616°  | 95                        | 80                         | 24               | *Thesium longifolium* Turcz. ex Ledeb. |
| 4, alluvial light-color-humus quasi-gley | N50.8631° E115.4651°  | 85                        | 70                         | 20               | *Equisetum arvense* L. |
| 5, alluvial light-color-humus quasi-gley | N51.0486° E114.3750°  | 65                        | 40                         | 17               | *Carex duriuscula* |
| 6, alluvial humus stratified | N50.4753° E114.0241°  | 55                        | 40                         | 9                | *Potentilla bifurca* L., *Carex duriuscula* |

### Table 2. Precipitation in the study area (according to Aginsk weather station), mm.

| Years    | I  | II | III | IV | V  | VI | VII | VIII | IX  | X  | XI | XII | mean annual |
|----------|----|----|-----|----|----|----|-----|------|-----|----|----|-----|-------------|
| 2016     | 3.9| 0.2| 18.1| 6.1| 28.7| 13.9| 31.3| 53.4| 84.5| 4.8| 8.0| 2.7| 256         |
| 2017     | 1.1| 3.5| 0.7 | 32.5| 24.3| 20.5| 58.7| 91.1| 36.2| 2.3| 1.9| 11.2| 284         |
| 2018     | 1.3| 1.6| 7.3 | 1.0| 14.0| 61.9| 253.4| 54.4| 65.0| 4.6| 0.7| 0.0| 465         |
| 2019     | 1.0| 0.0| 5.0 | 6.0| 1.0 | 72.0| 84.0| 98.0| 54.0| 6.0| 8.0| 0.0| 335         |
| mean annual | 0.0| 0.0| 0.0 | 8.0| 29.0| 59.0| 98.0| 76.0| 44.0| 8.0| 3.0| 0.0| 325         |

The aboveground and underground phytomass reserves were determined in the third decade of July. The maximum stocks of root mass and the highest productivity of grasses occur at this period. The herbage was cut at the soil surface in plots of 50×50 cm with 5 replicates. Simultaneously, the amount of died phytomass formed by the end of the growing season, and the felt accumulation were estimated. The underground mass reserves in the communities were studied by the monolith method followed by washing on soil sieves. In each coenoses, soil monoliths were sampled at three 25×25 cm plots layer-by-layer every 10 cm to 20 cm depth in 3 replicates. The aboveground mass and washed roots were dried to an air-dry state and weighed.

After wet ashing, total nitrogen [18] and phosphorus were determined in plants by a photometric technique [19]; potassium and sodium – by a flame photometric one [20–21]; after dry ashing, calcium and
magnesium – by a complex metric method [22]. Sulfur in plant samples was defined by a turbidimetric technique [23], carbon – by a Tyurin method modification [24], silicon – by weight method [25]. Indicators of litter-fall index (LFI), C:N, C:P, C:N:S:P, Ca:K ratios were calculated. Statistical data processing was carried out in Microsoft Excel.

3. Results and Discussion

3.1. Stocks and distribution of died phytomass and felt

The steppe felt has occurred in each coenosis, but its accumulation differs significantly across communities (table 3), and depends mainly on the died phytomass stock entering at the end of each growing season. The variability of the felt accumulation is due to the different coenosis structure, the heterogeneity of soil and environmental conditions, and effect of external factors (grazing, burning). It should be noted that the correlation coefficient of died phytomass and felt content is moderate (r=0.44). This is due to natural factors, in particular, heavy spring-early summer winds carrying out died phytomass at distance, which is typical for Transbaikalia.

Table 3. Content of died phytomass and felt in Leymus chinensis coenoses, g/m² a year (n=5).

| Number of descriptions | Died phytomass | Felt | Litter-fall index (LFI) |
|------------------------|----------------|------|------------------------|
|                        | M±m           | V, % | Lim                    | M±m           | V, % | Lim |
| 1                      | 35.8±7.9      | 49   | 21.4–61.4               | 70.6±12.3     | 39   | 33.6–110.4   | 2.0  |
| 2                      | 62.5±11.2     | 40   | 31.8–98.9               | 107.5±18.5    | 38   | 55.3–148.3   | 1.7  |
| 3                      | 102.9±21.6    | 47   | 54.5–182.4              | 78.4±8.7      | 25   | 55.3–102.0   | 0.8  |
| 4                      | 80.7±10.8     | 35   | 48.1–131.0              | 54.5±10.2     | 46   | 31.6–99.4    | 0.7  |
| 5                      | 11.2±3.2      | 64   | 6.6–23.8                | 76.0±7.8      | 23   | 51.9–96.0    | 6.9  |
| 6                      | 2.9±0.4       | 31   | 1.8–4.0                 | 26.2±2.3      | 19   | 17.2–29.2    | 8.7  |

Note: M±m – arithmetic mean and error of mean; V – coefficient of variation; Lim – limits of mortmass change.

The low amount of died phytomass in Description 6 is due to a significant proportion of annuals and biennials (33.3 % of the total species composition), as well as in Description 1 (21 %). As a rule, they are forbs with a short growing season, quickly turning into died phytomass, which in turn replenish the felt stocks and is mineralized. This is confirmed by the LFI value characterizing the rate of aboveground mortmass decomposition, i.e. the more is LFI, the faster the felt is utilized.

The main portion in the aboveground phytomass formation belongs to green shoots, in contrast to the territories of the Russian European part and West Siberia [3], it is 61–83 % (figure 1). The proportion of died phytomass varies from 12 to 22 % in Descriptions 1–4, while its amount is the lowest – 2 and 4 % in Descriptions 5–6. This is related to the floristic composition in Description 5, and grazing load in Description 6. The felt amount is 15–28 % of the total aboveground mass.

3.2. Felt chemical composition and element ratio

A specific feature of the felt chemical composition under the leymus coenoses is relatively high content of crude ash, Ca, and S (table 4). Concerning nitrogen, sulfur, and calcium amount in the felt, the haloxerophytic leymus community (Description 1) is superior to the others, because the saline soil is enriched with mineral salts. It should be distinguished a community (Description 6) with higher concentrations of nitrogen, phosphorus, potassium, and magnesium in the felt mineral composition, which is possibly related to the botanical composition and unregulated grazing of animals secreting their vital activity products, and enriching the felt by these elements. Other communities are characterized by almost equal content of these elements.
The died phytomass intensive decomposition is possible only at a certain level of nitrogen content in it. Nitrogen lack limits greatly the mineralization rate, but it does not go to the end. If nitrogen amount in the decomposing residues does not exceed 1.5 %, there is no accumulation of its mineral form in soil, as all nitrogen is bound by microorganisms. Nitrogen mineralization starts at C/N=20 ratio. However, it is known that this value can change depending on the nature of the chemical compounds of plant tissues. While decomposing plant residues of different species, nitrogen mineralization stops at different C/N ratios, and the critical value of the total index varies in the range 16.1–23.8 [26].

The paper presents a complete characterization of all components of coenoses, the element ratios in the aboveground and underground phytomass, and separately – for L. chinensis. According to the data obtained (table 5), C/N ratio is individual for each component: L. chinensis, herbs, died phytomass, felt, underground phytomass. In C/N terms, died phytomass and felt are hardly degradable, regardless of soil and environmental conditions of the coenosis.

The important factors affecting the decomposition rate are the content of ash nutrition elements in the mortmass, and the qualitative composition of these elements. A particularly important role is played by phosphorus content, which mineralization becomes possible only at certain C/P ratios. This ratio should be <112 [26]. If it is in 112–501 range, then soil phosphorus immobilization takes place. The most favorable conditions for the decomposition processes are created, when the C:N:S:P ratio is 100:8:1:1.2 [27]. Judging by C/P ratio values, died phytomass and felt in all coenoses are difficult mineralized (table 6), except for Description 6.

C:N:S:P ratios in died phytomass and felt do not correspond to the phytomass decomposition conditions, that along with high silicon content is the reason for the long period of felt mineralization in southeastern Transbaikalia (table 7). According to the data (table 8), Ca/K ratio value in green phytomass is relatively low, that is due to dominating grasses growing in the coenoses. However, it increases significantly in died phytomass and felt (except for Description 6) compared with green phytomass, because potassium can intensively washed out by precipitation. This indicator lower values in Description 6 are associated with the coenosis floristic composition.

Table 4. Felt chemical composition under leymus coenoses, %.

| Number of descriptions | N   | C     | Crude ash | P    | K    | Ca    | Mg    | S     | Na    | Si    |
|------------------------|-----|-------|-----------|------|------|-------|-------|-------|-------|-------|
| 1                      | 1.04| 28.12 | 9.58      | 0.16 | 0.20 | 0.57  | 0.14  | 0.62  | 0.16  | 3.44  |
| 2                      | 0.84| 42.60 | 9.17      | 0.14 | 0.19 | 0.51  | 0.15  | 0.31  | 0.04  | 3.27  |
| 3                      | 0.79| 42.12 | 7.89      | 0.19 | 0.21 | 0.37  | 0.10  | 0.27  | 0.04  | 4.14  |
| 4                      | 0.73| 41.77 | 9.90      | 0.29 | 0.28 | 0.50  | 0.15  | 0.33  | 0.02  | 3.92  |
| 5                      | 0.89| 34.54 | 8.68      | 0.27 | 0.41 | 0.51  | 0.13  | 0.36  | 0.02  | 3.68  |
| 6                      | 1.40| 38.23 | 9.19      | 0.36 | 0.63 | 0.45  | 0.30  | 0.39  | 0.04  | 2.74  |
### Table 5. C/N ratio value in the phytomass of leymus coenoses in eastern Transbaikalia.

| Phytomass       | Number of descriptions |
|-----------------|------------------------|
|                 | 1          | 2          | 3          | 4          | 5          | 6          |
| **Aboveground** |            |            |            |            |            |            |
| *Leimus chinensis* | 22.5      | 22.8      | 33.2      | 31.9      | 20.8      | 20.0      |
| herbs*          | 15.9      | 28.2      | 26.7      | 19.3      | 18.0      | 18.3      |
| died phytomass  | 31.8      | 69.4      | 50.7      | 75.8      | 46.7      | 37.5      |
| felt            | 27.0      | 50.7      | 53.3      | 57.2      | 38.8      | 27.3      |
| **Underground** |            |            |            |            |            |            |
| Soil horizon: 0–10 cm | 24.0  | 28.0      | 36.8      | 30.7      | 20.5      | 16.2      |
| 10–20 cm        | 19.6      | 22.3      | 30.3      | 17.5      | 22.3      | 16.7      |

* – Hereinafter: other species in the community.

### Table 6. C/P ratio value in the phytomass of leymus coenoses in eastern Transbaikalia.

| Phytomass       | Number of descriptions |
|-----------------|------------------------|
|                 | 1          | 2          | 3          | 4          | 5          | 6          |
| **Aboveground** |            |            |            |            |            |            |
| *Leimus chinensis* | 108.7     | 122.6     | 135.4     | 184.9     | 176.5     | 182.1     |
| herbs           | 105.2     | 147.8     | 132.7     | 132.6     | 160.1     | 198.3     |
| died phytomass  | 132.9     | 146.0     | 192.2     | 251.3     | 269.2     | 270.3     |
| felt            | 175.7     | 304.3     | 221.7     | 144.0     | 127.9     | 106.2     |
| **Underground** |            |            |            |            |            |            |
| Soil horizon: 0–10 cm | 150.7 | 133.7     | 114.1     | 197.1     | 118.1     | 72.2      |
| 10–20 cm        | 146.1     | 96.2      | 99.2      | 103.9     | 91.2      | 83.6      |

### Table 7. C:N:S:P ratio value in the phytomass of of leymus coenoses in eastern Transbaikalia.

| Phytomass       | Number of descriptions |
|-----------------|------------------------|
|                 | 1          | 2          | 3          | 4          | 5          | 6          |
| **Aboveground** |            |            |            |            |            |            |
| *Leimus chinensis* | 54:2:1:0.5 | 114:5:1:0.9 | 194:4:1:0.9 | 131:4:1:0.6 | 99:5:1:0.6 | 72:4:1:0.4 |
| herbs           | 28:2:1:0.3 | 74:3:1:0.5 | 57:2:1:0.4 | 74:2:1:0.5 | 69:4:1:0.4 | 69:4:1:0.3 |
| died phytomass  | 87:3:1:0.6 | 106:2:1:0.7 | 211:2:1:1.1 | 199:3:1:0.8 | 159:3:1:0.6 | 115:3:1:0.4 |
| felt            | 45:2:1:0.3 | 137:3:1:0.5 | 156:3:1:0.7 | 127:2:1:0.7 | 96:2:1:0.7 | 98:4:1:0.9 |
| **Underground** |            |            |            |            |            |            |
| 0–10 см         | 104:4:1:0.7 | 174:6:1:1.3 | 95:3:1:0.8 | 84:3:1:0.4 | 79:4:1:0.7 | 67:4:1:0.9 |
| 10–20 см        | 68:3:1:0.5 | 68:3:1:0.7 | 56:2:1:0.6 | 56:3:1:0.5 | 52:2:1:0.6 | 62:4:1:0.7 |

### Table 8. Ca/K ratio value in the phytomass of of leymus coenoses in eastern Transbaikalia.

| Phytomass       | Number of descriptions |
|-----------------|------------------------|
|                 | 1          | 2          | 3          | 4          | 5          | 6          |
| *Leimus chinensis* | 0.26      | 0.20      | 0.26      | 0.30      | 0.23      | 0.21      |
| herbs           | 0.35      | 0.43      | 0.43      | 1.07      | 0.42      | 0.61      |
| died phytomass  | 1.14      | 1.04      | 1.37      | 2.93      | 0.84      | 0.62      |
| felt            | 2.85      | 2.68      | 1.76      | 1.81      | 1.24      | 0.71      |
4. Conclusion
Thus, at present the felt stocks in leymus coenoses of southeastern Transbaikalia are 54–107 g/m². The died phytomass content depends on the coenosis species composition, soil and environmental conditions of their growth, and the grazing load degree. The litter-fall index indicates a low rate of felt decomposition. At the same time, in Leymus coenoses containing a relatively large number of annuals and biennials, low died phytomass is formed, which can accelerate the felt decomposition. The felt chemical composition of different coenoses reveals its dependence on soil and environmental conditions (nutrient and moisture supply). According to the values of C/N, C/P, C:N:S:P and Ca/K ratios in the aboveground phytomass of communities, it has been established for the first time that died phytomass and felt are highly resistant to decomposition and mineralization. However, the resistance level can be adjusted subject to changes in species composition, climatic (drought, heavy rainfall), and anthropogenic conditions (spring burnt and steppe fires).

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