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of open ecotopes acquire strong positions. As regards the hygromorphs in young cuttings, xerophytes increase their positions in communities, hygrophilous species retain their portion unchanged in the course of the succession, while the species of intermediate moisture requirement reduce in number. With the development of the forest vegetation, the compositions of coenomorphs, heliomorphs, and hygromorphs gradually return to their original state.

Thus, forest recovery in cuttings is rather successful. Direction and course of this process may abruptly change, influenced by possible thermokarst manifestations. In this case the secondary succession represents not an ordinary recovery process, but a peculiar "primary" one, called quasi-primary by Rabotnov (1983). This may result in the formation of both moist types of larch forests, *yernik* formations, grass bogs, or cauldron lakes (Utkin 1960; Tyrtikov 1969; Pozdnyakov 1983, 1986). A scheme of the vegetation dynamics in cuttings is given in Fig. 4.5.

4.5 Natural Fodder Lands of Central Yakutia

4.5.1 Hayfields and Pastures

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A thousand years of experience of cattle- and herd horse-breeding in Yakutia indicates the rather long-term process of developing the natural fodder lands for pastures and hayfields in the enormous territory of Northeast Eurasia. During that period the ancestors of the Yakuts first settled in the Middle Lena River region and the Lena-Amga Interfluve (Basharin 1956).

The extreme climatic conditions (cold winters lasting nine months, short droughty summers, cold soils, and perennially frozen grounds) forced the nomadic migrants to change their lifestyle, switching to settled cattle-breeding. During their centuries-old history the Yakuts have worked out the system of scattered stock keeping in small alases and in river valleys. The size of the livestock pool was determined by the capability to maintain them in droughty years. Herds of horses and cattle grazed on the rather vast grasslands of the three valleys of the Middle Lena River (Tuymaada, Erkeeni, Enseli), as well as in the valleys of the Tatta and Amga Rivers and in taiga alases.

Exploring Siberia in the seventeenth century, the Russians found the established settled stock-breeding economy of the Yakuts in the Middle Lena region and the Lena-Amga Interfluve (Central Yakutia). With increased livestock of cattle and horses, practically all the suitable hayfields and pastures had been set aside by the first quarter of the nineteenth century. An economic description of grassland management as an agricultural sector of Yakutia was first made by V.N. Poryadin in 1926, who participated in the expedition of the Academy of Sciences of the USSR aiming to study the agriculture of Yakutia. At that time the condition of the grasslands did not cause anxiety, since no sign of their degeneration due to anthropogenic pressure was obvious.

At present, significant areas of hayfields and pastures of Central Yakutia are in imperfect condition as a result of the absence of land improving arrangements, water-logging and remoteness.

The best natural fodder lands of Central Yakutia are represented by the following types of grasslands of various topologies: floodplain, alas and lakeside, upland, and small river valley meadows (Kononov et al. 1979).

Floodplain meadows cover the largest areas in the Lena River floodplain, as well as the rivers of the second and third order: the Viluy, Aldan, Amga, and Tatta. The average productivity is 10–18 centners per ha (c/ha) (= 1000–1800 kg per ha) of hay, comprising 37% of its gross production.

Shortly flooded (stepped) meadows are confined to high levels of a central floodplain. In some years they are flooded when ice jams are formed in a river causing the water level to rise. The soils are stepped-meadow, stratified, carbonate loamy and loamy sandy. The floristic composition of stepped meadows includes up to 40–50 species. They are mainly grasses *Agrostis trinii, Hordeum brevisubulatum, Elytrigia repens, Bromopsis korotkiji, Koeleria gracilis;* forbs *Artemisia jacutica, Galium verum, Saussurea amara,* and sedges (*Carex duriuscula*) with an occurrence of legumes *Lupinaster pentaphyllus, Vicia cracca, Medicago falcata,* etc. The productivity of shortly flooded meadows is low, 3–4 c/ha of hay.

Medium flooded (true) meadows occupy the largest part of a central floodplain, as well as parts of the lower and upper floodplains, exposed to flooding for 3–4 weeks. The soils are frozen alluvial soddy soils, with a high content of humus (from 10 to 11% in the upper horizons to 0.4–0.7% in the lower horizons at a depth of 20–30 cm). The vegetation is predominated by mesoxerophytes. The average productivity is 10–12 c/ha of hay. Various types of grass communities (*Hordeum brevisubulatum, Elytrigia repens, Agrostis gigantea*) are of special economic significance, giving a productivity up to 10–15 c/ha of hay.

Long flooded (swamped) meadows develop under conditions of prolonged flooding and are characteristic for floodplain depressions. The soils are frozen alluvial peat-gley soils. The species diversity is low with hygromesophytes as edificators: *Glyceria triflora, Equisetum palustre, Calamagrostis langsdorffii, Scolochloa festucacea, Carex disticha, C. acuta.* The communities with *Calamagrostis* are characterized by highest productivity, thus representing valuable hayfields. They typically cover large areas though often they are strongly tussocky.

By gross hay production the floodplain meadows rank second after the alas meadows.

Small river (taiga river) valley meadows represent a special variety of floodplain meadows and are situated in the valleys of small taiga rivers. By gross fodder production they take the third place (26%) and are mainly used as summer pastures for cattle and winter pastures for horses. The soils they grow on vary widely: frozen meadow-bog, muddy-bog, peaty, peaty-bog, and frozen soddy-meadow types. The vegetation is dominated by *Calamagrostis langsdorffii, Carex schmidtii* and *C. juncella,* the latter two species forming tussocks of various height (10–60 cm) in cold and overwetted habitats. The dryer areas are covered with bluegrass

communities with a prevalence of *Poa pratensis*, occurrence of *Alopecurus arundinaceus*, *Bromopsis inermis*, *Vicia cracca*, and forbs.

Upland meadows occupy the drained and flood-free sectors of the valleys and dry ravines. They also may represent secondary communities on stubbed out lands and in post-residential areas. These meadows are used as summer and early spring pastures providing 1% of the fodder. The vegetation consists of forbs-*Elytrigia repens* communities with a prevalence of *Elytrigia repens*. Abundant forbs are *Sanguisorba officinalis, Thalictrum simplex* and *Galium verum*. Sometimes sedge-forbs or sedge-*Elytrigia repens*-forbs meadows occur with participation of *Carex duriuscula*.

Alas and near-lake meadows are most typical for the Lena-Amga Interfluve and the Viluy River basin. They provide with up to 36% of the Yakutian hay making with a productivity of 4–13 c/ha depending on certain weather condition during the year. These meadows are situated in depressions of various origins, mostly of thermokarst.

The vegetation basically consists of the grasses *Hordeum brevisubulatum, Elytrigia repens* and *Puccinellia tenuiflora* and forbs *Artemisia mongolica, A. jacutica* and *Salicornia perennans*. Various *Cyperaceae* grow all along the moisture gradient from xerophytic (*Carex duriuscula*) to aquatic (*Scirpus lacustris*) habitats. Alas grasslands are characterized by a concentric distribution of plant communities around a lake. Basically, three belts are distinguished: the upper, middle and lower. The upper belt represents the habitat for xerophytes: *Stipa capillata, Elytrigia repens, Agrostis trinii, Koeleria gracilis*. The middle belt is covered with communities of *Hordeum brevisubulatum, Sanguisorba officinalis, Thalictrum simplex, Poa pratensis* and *Puccinellia tenuiflora*. The latter species serves as an indicator for this belt. *Alopecurus arundinaceus, Calamagrostis langsdorffii, Beckmannia syzigachne, Glyceria triflora, Scirpus lacustris* grow in the lower belt of alases. Depending on weather conditions during the growing season, the alas grasslands feature pronounced perennial and seasonal dynamics, so that the belt communities may change in width and spatial position each year, and strongly vary both in productivity and nutritional value of the forage.

Alases of river origin occur more rarely, and mainly occur in the Viluy River basin. They are confined to taiga river valleys and represent nearly flat, hardly noticeable depressions of a roundish or elongated form. Sometimes they appear as a result of drainage and drying out of taiga lakes.

4.5.1.1 Hayfields

From the total area of hayfields of Central Yakutia flooded hayfields comprise 17%, of them 13% being clean (i.e. featuring no shrubs, tussocks, litter, etc.); 59% go for upland meadows, of them 5% being improved and 51% clean. The recent 30–40 years are characterized by a tendency of decreasing productivity of the natural fodder lands. Following the data of the State Committee of Statistics of the Republic

of Sakha (Yakutia), the hay harvesting rates are characterized by a 30–40% reduction, and hayfield productivity has decreased 2.2–2.5 times (Desyatkin 1996). By January 1, 2007, the livestock numbered 259.2 thousand heads, including 103.2 thousand milk cows, and 134.5 thousand horses. Natural hayfields and pastures occupy 718 thousand and 794 thousand ha respectively, providing only 40–50% of the required forage protein. Only 62% of the hayfields were used in 2007, since about 270 thousand ha were flooded, deserted, or were hard to access due to their remoteness. Meadow swamping rates increase every year, comprising now 24% of the total hayfield area. Due to shrub invasion and presence of tussocks, swamped meadows are used only for 50–60%.

Figure 4.6 shows that since the 1960s (the period of large collective farms establishment) the hayfield productivity in Yakutia has declined, even though their area has increased.

The traditional stock-breeding system that has established in Yakutia during the recent decades does not imply a clear division of grasslands into hayfields and pastures, resulting in strong degradation of the fodder lands near the settlements in Central Yakutia (especially in the Lena-Amga Interfluve). Another major reason of grassland degradation is soil compression as a result of the technogenic activity of various vehicles. This first refers to agricultural machinery, tractors and their trailers. The modern hay harvesting methods imply multiple passages of machinery. As a result, their wheels and caterpillars damage 10–15% of the total hayfields area (Denisov and Prokopyev 1979).

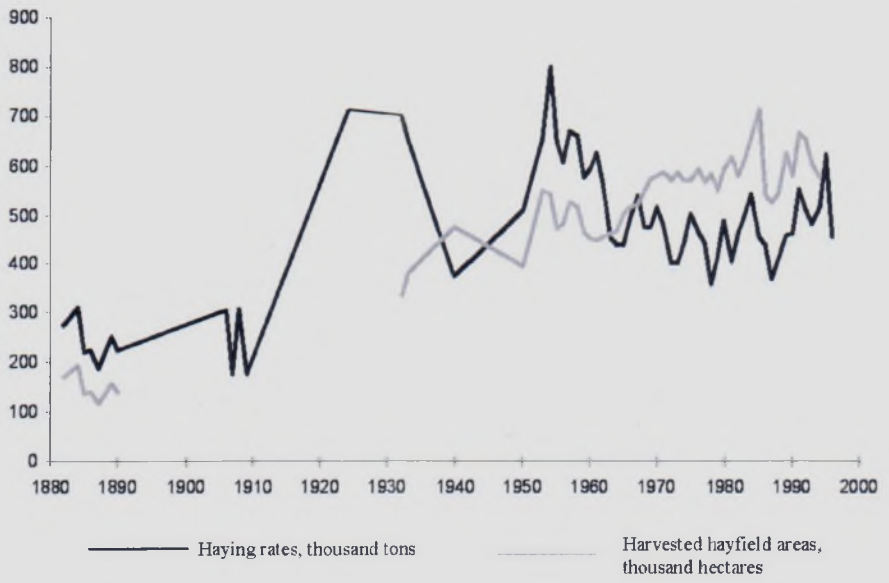

Fig. 4.6 Haying rates and hayfield areas in Yakutia for the period of 1882–1996 (based on the analysis of literature data)

A special classification of alas vegetation (fodder types) was elaborated to be used for Yakutian fodder land characterization (Kononov et al. 1979; Gogoleva et al. 1987; Gavrilyeva 1998; Gerasimova and Gavrilyeva 2001; Savvinov et al. 2005). The following is a list of vegetation fodder types best suitable for haying.

Forbs-*Bromopsis* type. The communities of this type grow mainly in forest edges, on the slopes of *baidjarakh*s and *bulgunnyakh*s. At that, only shaded eastern-, western-, and northern-facing slopes are used as hayfields. The grass stand is usually dense (projective cover up to 90%), high (average height 70–80 cm) and is characterized by a rich species composition with predomination of *Bromopsis korotkiji, Pulsatilla flavescens, Veronica incana,* etc. The average productivity is 14–15 c/ha.

Elytrigia type. These communities are common in upper and middle alas belts. The projective cover is 60%, the height of the grass stand is 40–60 cm. The productivity varies significantly depending on weather conditions and amounts to 10.4 c/ha on average. In spring and autumn such communities serve as pastures for cattle. The vegetation is dominated by *Elytrigia repens*. Other characteristic grass species are *Hordeum brevisubulatum, Poa stepposa, P. pratensis* and *Agrostis trinii*. Also *Carex duriuscula* and forbs (predomination of *Artemisia commutata* and *Saussurea amara*) grow there.

Puccinellia type. Mesic habitats support the domination of *Puccinellia tenuiflora* (80–90%) with a projective cover up to 80% and an average height up to 70 cm. The average productivity is 22.0 c/ha, and also depends on yearly weather conditions and soil salinity. Other community components are scarcer: *Hordeum brevisubulatum, Alopecurus arundinaceus, Knorringia sibirica, Saussurea amara, Glaux maritima*. Litter is absent in this type.

The *Hordeum* type is not common in alases and occupy the middle mesic belts. The grass stand is dense (95%), with an average height of 90 cm, and a productivity of 20.7 c/ha. The most representative species of this type are the grasses *Hordeum brevisubulatum, Poa pratensis, Elytrigia repens,* etc.; the forbs *Sanguisorba officinalis, Thalictrum simplex, Geranium pratense, Gentiana macrophylla, Silene repens, Galium verum,* etc.; as well as legumes. The meadows represent high quality hayfields.

The *Alopecurus type* is widely distributed in the lower vegetation belts. It is characterized by a dense (95%) and high (70 cm) grass stand with a productivity of 25.3 c/ha. The dominant species are *Alopecurus arundinaceus, Poa pratensis, P. palustris, Agrostis stolonifera* and *Carex lithophila*.

The *Carex-Calamagrostis* type is confined to overwetted lake-sides (lower belts of alases). The communities of this type feature tussocks formed by *Carex juncella*. Projective cover is 80%, height 90 cm, productivity 19.8 c/ha. Dominant species are *Carex juncella* and *Calamagrostis neglecta*; co-dominants are *Alopecurus arundinaceus, Agrostis stolonifera, Carex lithophila, C. atherodes* and *C. disticha*. These communities contain litter.

As mentioned before, there are no alases nowadays that would be used strictly for hay harvesting. In early spring and in autumn they serve as pastures (Gavrilyeva 1998).

4.5.1.2 Pastures

Traditionally, grazing lands are situated around residential areas and summer cattle farms. Like hayfields, the main pastures of Central Yakutia represent grassland vegetation of alases (55% of their total area), floodplains (up to 23%), taiga river valleys (up to 17%), and uplands (up to 4%), including forest communities. The topological location of the grasslands determines the seasonality of grazing. Thus, spring pastures are situated on floodplain ridges and upland meadows, in the upper belts of alases, and on steep slopes with steppe vegetation. Summer pastures (grazing from early June onwards) represent inter-ridge depressions of above-floodplain terraces, alas belts of variable moisture conditions with *Hordeum brevisubulatum* and *Alopecurus arundinaceus,* as well as sedge and swamped vegetation.

The Soviet period's enlargement and consolidation of collective farms, established near large settlements, has led to a reduction in the total pasture area due to desertion of remote fodder lands. In contrast, the nearby grazing lands have become overstocked by an even smaller amount of livestock (Sofronov and Karpov 1999; Nikolaeva and Sofronov 2001). The area of trampled, salinized, and low-productive pastures totals now 230 thousand ha in Central Yakutia. Overgrazing results in exhaustion of the vegetation cover and compression of the upper soil layer, yielding a complex of ecological transformations. Increased soil solidity raises capillary pressure. This leads to rising salt concentrations in saline soils, the appearance of trampling-induced hillocks on wet soils, and the transformation of dry habitat soils of light mechanical structure into dust (Kononov et al. 1979; Mironova and Poiseeva 1996). All these signs of pasture degradation are especially pronounced in alases, since most settlements and cattle-breeding husbandries are situated in these peculiar landforms (Denisov et al. 1983).

The following are the basic fodder types of pasture vegetation (Kononov et al. 1979; Gogoleva et al. 1987; Gavrilyeva 1998; Gerasimova and Gavrilyeva 2001; Savvinov et al. 2005).

The *Stipa-Koeleria* type is characteristic for valley and *baidjarakh* slopes. Its projective cover is 80%, its average height 70 cm and its average productivity 8.8 c/ha. Major species are *Stipa krylovii, S. capillata, Festuca lenensis, Poa stepposa*, *Carex duriuscula,* etc. This type is used as spring pasture.

The *Koeleria-Carex duriuscula* type is situated in the upper xeric belts of alases and on above-floodplain terraces, indicating moderate pasture pressure. About 50% of the species composition goes for sedges (*Carex duriuscula*). The average projective cover is 30%, the average height 10 cm, and its productivity 8.5 c/ha.

With increased grazing load the previous type transforms into the *Carex duriuscula* type, characterized by a lower productivity (4.4 c/ha), and average height (up to 5 cm). The projective cover remains unchanged making up 30% on average. Grasses disappear or decrease in abundance in the community, 30–50% of the grass stand being represented by *Carex duriuscula.* Ruderal forb species (*Artemisia jacutica, Lepidium apetalum, Chenopodium album,* etc.) on the contrary, strengthen their position, comprising 35–60% of the grass stand.

The *Puccinellia* type differs from its hayfield variant both by a significant biomass reduction (up to 6.4 c/ha) and a change in floristic composition. *Puccinellia tenuiflora* loses its dominating position, giving way to *Elytrigia repens, Poa pratensis* and *Agrostis stolonifera*. Grasses make up 20–80% of the grass stand. The proportion of forbs (*Taraxacum ceratophorum, Plantago media*, sometimes *Descurainia sophia, Lepidium densiflorum*) is also increased.

Increased grazing induces replacement of the *Puccinellia* type by the *Potentilla anserina* type with a projective cover up to 60%, an average height of 5 cm and an average productivity of 8.3 c/ha. Grasses are suppressed and give way to creeping and rosette forbs (*Potentilla anserina, Plantago media, Knorringia sibirica,* etc.).

The *Alopecurus* type also significantly reduces the proportion of grasses under grazing conditions in favour of forbs (*Potentilla anserina, Armoracia sisymbrioides, Persicaria amphibia*). Species number is lower, the projective cover makes up 60%, the average height is 40 cm, and the productivity 11.8 c/ha. In wetter habitats with increased grazing pressure the *Alopecurus* type transforms into the *Eleocharis-Alopecurus* and *Eleocharis-Potentilla* types, representing two different stages of pasture degradation.

The *Eleocharis-Alopecurus* type features dominance of *Eleocharis palustris, Sparganium emersum, Carduus crispus, Armoracia sisymbrioides* or *Knorringia sibirica;* and the grasses *Alopecurus arundinaceus* and *Beckmannia syzigachne* occupy 10–60% of the grass stand. The average projective cover is 70%, and productivity 13.8 c/ha. Water-logging and trampling-induced hillocks in the lower alas belts are also characteristic for this fodder type.

The *Eleocharis-Potentilla* type represents communities with a dominance of *Eleocharis palustris* and *Potentilla anserina.* Grasses (*Alopecurus arundinaceus, Puccinellia tenuiflora*) almost disappear comprising only 5% of the grass stand. The latter is dense (up to 95%), its average height is 30 cm, and its productivity up to 27.6 c/ha.

The grazing variant of the *Carex-Calamagrostis* type has a high density of tussocks and predominance of *Carex juncella* and *Calamagrostis langsdorffii.* Compared to hayfields, the average height decreases to 40 cm and the productivity to 14.1 c/ha or lower. From year to year, much litter is accumulated between the tussocks (10–15%).

Applying the ecological principles of the rational use of natural fodder lands allows both to stabilize the negative processes and increase the productivity of hayfields and grazing lands.

4.5.2 Grazing Effect on Forest Communities

I.F. Shurduk and A.P. Efimova

The valley forests also suffer from trampling and grazing. This results in a change in the relative size of the different ecological-coenotical species groups; in a decrease in the abundance of dominants and subdominants; in a reduced vitality of plants,