2012

# Recruitment of *Larix sibirica* Ledeb. in Closed Forest Stands, on Clear-Felling Sites and at Fire-Sites in the Forests of Mongolia

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Erforsch. biol. Ress. Mongolei (Halle/Saale) 2012 (**12**): 365–370

# Recruitment of *Larix sibirica* Ledeb. in closed forest stands, on clear-felling sites and at fire-sites in the forests of Mongolia

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## Abstract

The paper deals with recruitment patterns in larch forests of Mongolia following anthropogenic impacts (felling, fires), and describes successional trends in highland forest communities. It is established that mass seed recruitment of *Larix sibirica* LEDEB. took place during anomalous combinations of hydrothermal conditions supposedly occurring at periods of about 100 years. During the last decades, frequent fires of various intensities put serious constraints on reforestation of the larch, and induced successional trends in disturbed forests.

**Key words:** *Larix sibirica*, Mongolia, forests, anthropogenic impact, fire, succession

## Introduction

A neutral material-energy balance, i.e. the gain in phytomass equals its loss, is an indispensable condition for realizing the productive potential of wood in ecosystems. This balance can only be achieved if recruitment at least compensates the loss of plants. Moreover, often only autochthonous breeds have the potential to show net-positive growth during reforestation of felling and fire-sites.

## Material and methods

Research was carried out on permanent trial areas (PTA), established in the 1970s to 1980s by Soviet and Mongolian scientists (FORESTS … 1978, 1983, 1988), and by the authors of this paper in 2006–2011 at the forest stations “Khialganat” and “Tosontsaengel” in Northeast and Central Khangay, and also “Gachuurt” and “Mongonmor’t” in Central and east Khentey. In total, the process of reforestation in Mongolia was analyzed on more than 70 PTA.

The patterns of natural seed recruitment of *Larix sibirica*, as the main forest-forming species in Mongolia, are clearly and convincingly demonstrated in the forests of Central Khangay. Temporary and spatial dynamics of recruitment of *L. sibirica* were studied here on a series of larch forests, representing 11 variants: 6 of them are overmatured stands differing in degree of disintegration; others are young stands on fire-sites and clear-felling plots of different categories. Table 1 shows baseline data on structure and formation of larch young growth.

It has already been shown that on clear-felling sites in Central Khangay the initial stages of recruitment of young larch trees pass through a shrubby (*Lonicera altaica* Pall.) succession stage (YARMISHKO et al. 2008).

## Results and discussion

In the notch Agtym (PTA-6a) the plot of larch forest (type: herb-sedge-*Rhytidium*) is located in the middle part of a northern slope with an inclination of 17–20º, and at an altitude of 1950–2000 m above sea level. 1540 units/hectare of mother trees and 720 units/hectare of young growth (FORESTS ... 1983) were observed in 1976. Now, young growth is absent and the stand represents an example of a partly dried stand with fallen deadwood. A thick (10–12 cm) cover of dry moss *Rhytidium rugosum* prevents seed germination and establishment. The rootlets of the

Table 1: Inventory of larch stands

| Rate<br>Number of trees, unit/hectare | PTA-6a | PTA-2b | PTA-7 | PTA-2 | PTA-4 |
|---|---|---|---|---|---|
| *Living trees* | 1160 | 1060 | 510 | 430 | 630 |
| Stand closure, relative unit | 0.9-1.0 | 0.6-0.7 | 0.4-0.5 | 0.2 | ≤ 0.1 |
| Σ Basal area m²/h | 39.3 | 32.1 | 22.8 | 6.5 | 4.0 |
| Average diameter, cm | 17.6 | 17.9 | 22.3 | 13.0 | 7.5 |
| Average height, m | 17.0 | 15.5 | 17.5 | 9.4 | 6.5 |
| Dry trees | 468 | 140 | 1600 | − | − |
| Fallen deadwood | 316 | 360 | × | − | − |
| Stubs, unit/hectare | 92 | 23 | 310 | 700 | × |
| *Young growth* | − | 260 | 5360 | 140 | 400 |
| **Phytomass, t/hectare** | | | | | |
| Trees: living | 145.0 | 123.9 | 89.8 | 23.0 | 11.4 |
| dry | 6.7 | 4.2 | 1.1 | − | − |
| fallen deadwood | × | 43.4 | × | − | − |
| Young growth | − | 0.3 | 13.0 | 0.1 | 0.4 |
| *Lonicera altaica* | | | | | |
| projective cover, % | − | 7.0 | 18.8 | 38.8 | 52.7 |
| phytomass, t/hectare | − | 0.207 | 0.817 | 1.981 | 2.113 |

□ = absent; × = not determined

abundantly present 3-year old larch seedlings marked here in 2007 penetrated only up to 7–8 cm into the moss over and did not reach ground litter or soil. These seedlings are condemned to die off in the poikilohydric conditions of the moss layer. Dense mother trees prohibit the growth of the few established young plants (shading, dense root layers and intense competition for water). A shrub layer, including *Lonicera altaica*, is absent.

In the notch Nariyn Burgastain (PTA-2b) herb-*Rhytidium* larch forest occupies the upper part of a flat (7–10º) northern slope at an elevation of 2022 m above sea level. The tree stand is at a stage of beginning disintegration and regressive development. More than half of fallen deadwood phytomass is formed by trunks (73 units/hectare) ranging in diameter from 40 up to 52 cm. These trees belong to the first and second generations, with ages varying from 250–280 to approximately 400 years (piths of large trunks in various stages of decay). The stock of fallen deadwood phytomass exceeds the average annual gain of standing tree phytomass by 40–50 times. A population of *Lonicera altaica*, formed mainly from vegetative runners, has formed a cover layer below the trees. The rare small growth of *Larix sibirica* living here is old (40–50 years), has a height of less than 2 m and must be categorized as “weakened” with respect to its vital conditions.

In virgin tree stands, the development of young growth over the 30-year’s observation period, its vitality and the appearance of new generations depend on the disintegration of dominant undergrowth, especially of *Lonicera altaica*. For example, in the *Thuidium*-herb highly productive larch forest of the notch Nariyn Burgastain (PTA-1a) the amount of dead trees (dry stands, windfall, fallen deadwood and stubs) exceeds the number of living units by 1.3 times (1685 against 1291 trees/hectare). In impassable tree stands broken by fall, the projective cover (PC) of *Lonicera altaica* reaches 16.3 %, and the number of established young growth has increased by more than 20 % since 1976. In other virgin larch forests, young growth has not survived over 30 years, or the extant populations are not viable.

Analysis of age structure of virgin tree stands, including also the age of established young growth, has shown that the recruitment of new generations occurs in abnormally moist cycles of years. These occur at intervals of 40–50 and even more years (SLEMNEV et al. 2012).

Two stands formed on clear-cut sites have also been surveyed in the notch Nariyn Burgastain. A *Rhytidium*-herb larch forest (PTA-7) is located in the middle part of a naturally terraced northeast-facing slope (8–10º) at an elevation of 1929 m above sea level. Trees were selectively cut (41 % of stocks) in 1964. In comparison with the estimates of 1976 (FORESTS … 1983) 70 % of adult trees survived to the present time. The number of young growth (in initial and subsequent stages of establishment) is only 25 % of what was recorded earlier. The most vigorous young growth is at the centre, and under crowns of *Lonicera altaica* bushes. The mass recruitment of larch (see table 1) is due to the orientation of the site to the warmer east sector, and due to its position on a flat terrace with a natural bank. This decreases drainage (surface flow and in the soil) and increases water availability at the site.

An herb-sedge young larch forest (PTA-2) was established on felling sites of 1964. The area is located on a flat (5–6º) terrace above the flood plain of the Burgastain river at an elevation of 1986 m above sea level. The community is characterized by high larch survival. The amount of initial and surviving young growth in 2007 comprises 80 % of numbers encountered 1976, and projective cover of *Lonicera altaica* has grown to 11.8 % during the observation period (FORESTS … 1983).

Young larch trees in the notch Elstein (PTA-4) on continuous felling (1975) occupy the middle part of a north-north-eastern slope (13º) at an elevation of 1965 m. The initially established young growth was protected by trees kept after logging (20 % or 1100 trees/hectare) at an age of 10–40 years (FORESTS … 1983). Now the young growth of initial and subsequent recruitment amounts to 1030 units/hectare indicating the high regeneration potential. The formation of healthy larch poles is promoted by an optimum environment under cover of *Lonicera altaica* bushes, PC of which has increased to 45 % over the period from 1976 to 2007. The young trees growing inside of forestlands present a fine example of successful larch regeneration in a favourable ecological environment provided by *L. altaica*.

However, in forest ecosystems of Central Khangay on clear felling, in contact to mountain steppes and cattle pastures, arid steppe communities have developed. Various grasses are common on new felling (as in the notch Mukhryn, PTA-3cb), covered by an herb-sedge community with the bush *Artemisia santolinifolia*. Shrubby undergrowth (*Lonicera altaica, Spiraea media, Rosa acicularis*) is absent in the community, and moss cover (*Rhytidium rugosum, Thuidium abietinum*) is at PC 5–7 % (compared to 45–50 % in adjacent larch forests with dry moss).

Herbs and sedges (PC up to 25–30 %) flourish on old felling (the notch Agtym, PTA-6), where they are joined by species from grassland, steppes (*Galium verum, Vicia cracca*, *Dianthus superbus, Allium senescens*), and even by those of digressive pastures (*Potentilla bifurca*). The formation of a closed sward, loss of soil moisture with the disappearance of long seasonal congelation, and constant grazing render emergence of seedlings and larch regrowth impossible.

Wide-ranging measures taken in the 1970s for reforestation on felling and under cover of trees (SAVIN & DASHZEVEG 1983) were apparently not successful. Not a single living individual of *Larix sibirica* remained to the present time on the numerous trial areas. This gives further evidence that successful recruitment of larch depends on continuous periods of above-average water supply of a duration not less than 10 years. It has to be emphasized for other regions of Mongolia that young growth is absent in overmatured and virgin tree stands of *Larix sibirica* (rare exceptions include flat terraces above flood plains of small rivers).

A rich herb-sedge community (60 species) developed in the taiga belt of the north-eastern Khangay at old fellings (the notch Shirman, PTA-1) situated on a flat terrace (2–3º) above a flood plain. Larch young growth is absent. Young growth of *Betula platyphylla* of both generative and vegetative origin occurs sparsely (230 units/hectare). Fires and the dense grass cover on fellings

(with thick litter of up to 8 – 10 cm) prevent the recruitment of *Larix sibirica*. This mode of growth restriction of larch forests is not widespread, and is confined to floodplains in valleys of the small rivers. In the long run, formation of tree stands at these areas will probably depend on a change of the occurring breed. In this belt, pure birch (or those with an insignificant addition of pines and larches) forests occur that are at an age of 70 – 80 years passing into a stage of disintegration. Young growth of coniferous trees is absent here or at most sparse (YARMISHKO et al. 2007).

In the same region, in low mountain taiga belt, felling sites varying in age are occupied by young (up to 10 years) birch growth, which had emerged after fire from a herb-sedge-wood-reed layer. The density of birch young growth depends on the elevation, inclination and orientation of mountain slopes. A community with birch trees numbering to up to 50000 units/hectare developed on clear-cut felling (the notch Khartsay, PTA-3) at 1500 m above sea level in the upper flat part of a northern mountain slope (10º). 7500 birch trees/hectare are found on fellings located on a flat (7º) terrace in the lower part of north-eastern slope at an elevation of 1300 m (the notch Bavgait, PTA-5). At the same time, young growth of *Larix sibirica* (200 units/hectare) is observed in dense birch forest while it is absent in sparse birch forest. Finally (with more insolation), a rich grass-bush undergrowth with PC 75 % develops. It is characterized by meadow and meadow-forest species: *Calamagrostis obtusata, Carex amgunensis, Fragaria orientalis, Rubus saxatilis, Vicia baicalensis, Lathyrus humilis, Geranium vlassovianum, Thalictrum minus.* The recruitment of larch and birch in such conditions is prevented by a constantly strong deficiency of moisture in the upper soil layers. In the taiga belt mixed stands of birches, larches and cedars give evidence of successional disintegration of aged communities.

In eastern Khangay, as well as in north-eastern Khangay, young birch growth, the age of which is defined by the last severe fire of 1996, has developed in the belt under taiga by felling of different age. These areas represent an initial successional stage of virgin larch forests after disintegration of former birch forests. During their development larch young growth may occur but never in large numbers because its occurrence is detrimentally affected by the competitive environment and – in communities adjacent to pastures – by grazing of domestic cattle. At least according to our research, the share of adult larches in birch plantings of various ages is low.

In the taiga belt of the notch Mukhar Gutay (PTA-4) (1705 m above sea level), the recruitment of mixed forest is extremely successful on conventional clear-cut felling being 30 years old. Here larches number to 3480, and birches to 440 units/hectare. The recruitment of trees occurs regularly at intervals of 5 – 7 years. The age of the dominant generation of *Larix sibirica* is 8 – 9 years. This gives evidence of the mass recruitment after destruction of tree stands by *Ocneria dispar* in 2002.

The dynamics of recruitment in this area may be illustrated by an example of larch-birch young growth (PTA-5) at the same notch. It developed on a felling of 1976 subjected to repeated fires. In 2008 the community counts 2380 trees/hectare of *Larix sibirica* and 2060 trees/hectare of *Betula platyphylla*, mainly of young growth. In 2011 the number of larch has decreased to 930 trees/hectare (loss 60 %), and birch down to 1120 trees/hectare (loss 46 %). The rapid loss of young trees over three years may be explained by strong water competition exerted by grasses and bushes. Between 2008 and 2011, PC of grasses has increased from 44 up to 75 %, and PC of bushes from 2 up to 12 %. The formation of birch growths in mixtures with *Larix sibirica* shows similar rapid dynamics.

The recruitment of larch at ecotones to forest-meadow steppes and to steppe communities is particularly interesting. For the first time the variants of such young forests were described by BANNIKOVA (2003) in the early 1970s. She figuratively described the young larches as “necklaces” surrounding the virgin tree stands as a narrow bent strip in the lower parts of slopes, and as a “belt fringe” on the edges of mountain woodlands. In historical aspect, the author considers the process of reforestation in mountain grassland communities as recurrent pulses of development

of mountain forest-steppe over the Holocene, when the steppe and forest elements changed their spatial positions in response to the given climatic situation (MOUNTAIN forest-steppe … 1983).

Colonization of meadow steppes by larch was observed in north-eastern Khangay, and to a lesser degree in Central Khangay (FORESTS … 1978). Dr. Korotkov also noted a wide occurrence of such young forests in eastern Khentey. A survey at the beginning of the 1980s determined the age of primary larch at 40 – 45 years. These tree stands are about 70 years old now, as their reforestation dates back to the 1930s (FORESTS … 1988). In the same period, mass recruitment of larch has apparently also occurred in western Khentey (DULAMSUREN et al. 2010). Moreover, the age of larch trees in notch Gachuurt does not exceed 70 – 80 years, too. Larch young trees being 40 years in age are less common in Central and eastern Khentey, even fewer are 20 years old. Under subsequent favourable natural conditions in this region a healthy vigorously growing tree stand may have formed from initially young stages.

A completely different situation is observed in pseudo-taiga larch forests of Central Khangay, where mass drying of bordering and banded tree stands takes place. Drying of single trees was observed on the forest edges and their vicinity during research trips in this region in 2002 and 2004 (SLEMNEV et al. 2012). According to assessments from 2007, the most intensive drying of banded tree stands occurs on the edges of stands at ridge crests, in contact to gaps, at the middle parts of wooded slopes, and on the edges of woodlands on mountain tops (YARMISHKO et al. 2008).

As an example, we describe a banded tree stand near the mountain pass Uver Teel (PC-9). A drying herb larch forest being about 1 ha in size (35 × 280 m) is located 3 – 5 m behind a crest of a ridge; the semicircular south-eastern slope below is occupied by steppe communities. Age of trees is 70 years, average height 9 m. The number of standing trunks is 5700 units/hectare, 9 % of these are alive.

Distinctly banded larch forests on the slopes of mountains, bordering young trees in the lower parts of slopes, have different structure and dynamics. For example, bordering larch forest with a high cover of dead wood and dry moss in the notch Agtym (PC-60 m) comprise two generations, 50 and 70 years, respectively. There are 43,800 trunks/hectare with an average height of 7.9 m. Of these, 48.4 % are dry standing trees. Drying of a large number of trees there may be a consequence of natural forest thinning due to intense competition for water.

The reason of drying of tree stands on the edge of forests is not, in our opinion, fire nor insects attacks. These natural disasters spread locally over continuous tracks of forests, instead of affecting narrow strips of wood that are difficult to access and are scattered across enormous territories.

Given that the age of all bordering, banded and drying tree stands in the forests of Mongolia is identical, we have to assume that the conditions of their recruitment (approximately 70 years ago) were similar too. The analysis of the climatic situation in the 1930s with respect to a complex set of parameters (meteorological observations, dynamics of annual gain of trees) shows that these years were abnormally wet (PEDERSON et al. 2001, DAVI et al. 2006) not only in the North of the country, but also in the desert zone of Mongolia (SLEMNEV et al. 2010). In conditions of favourable moisture over this sequence of years recruitment of *Haloxylon ammodendron* took place in the extremely arid desert Za-Altay Gobi. Differences in formation and development of banded and bordering young growth in ecosystems of Central Khangay and eastern Khentey are determined by transportation of precipitation. It was Atlantic in the first case and extratropical monsoonal in the second.

In summary, we describe the main patterns of recruitment in the larch forests of Mongolia based on data mainly coming from key study sites, chosen in 1970s. The present selection was made with all respect to Dr. Ivan Alexandrovich KOROTKOV – the author of classification of forest types and excellent scholar of woodlands of Eurasia.

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