Mountain forest-tundra ecotone response to climate change (Altai-Sayan Mountains, Siberia)

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In Eurasia the most significant climate change have occurred in Siberia; fast further temperature increase and precipitation change in the next decades is predicted.

The annual pattern of climate variables in the forest-steppe ecotone (mean for the 1961-1990 yr)
1, 2 – temperature, 3, 4 – precipitation in Altai and Tuva Mountains

A climate in the study areas is severe continental
Tree response to climate trends is most likely in the zone, where namely temperature and precipitation limits growth, i.e., in the forest-tundra ecotone.

We investigates tree response changes in the mountain and northern forest-tundra ecotone.

The study parameters are tree apical and radial increments, regeneration dynamics, and canopy closure.
The mountain forest-tundra ecotone areas in focus:
1. Sayan Mountains
2. Tuva Mountains
3. South Altai Mountains

The Altai-Sayan Mountains are the system of ridges divided by a dense hydronet on the Siberia south
Forest-tundra ecotone in the Altai and Tuva Mountains is formed by larch (on dry mega slopes)…
... and by Siberian pine (on the moisture mega slopes).
Trees responding to climate trends by transforming from prostrate forms to arboreal...
... and by migrating into tundra zone

Larch is surpass Siberian pine in frost and drought resistance, and growing arboreal where pine is prostrate.
A strong increments increase is observing since the mid of 80s with high correlation with summer temperature (R=0.61-0.64)

Siberian pine
Apical (1) and radial (2) increments of "post-prostrate" forms of (A= 95 yr);
5 - radial increment of mature trees.

Larch:
(3) Apical and (4) radial increments
6 - mean-summer temperature.
Straight lines: trends (p<0.01).
An increase of regeneration number is observing in the forest-tundra ecotone during last decades

The regeneration number correlates with a temperature and precipitation trends.

Siberian pine regeneration age-structure and heights distribution. 1 – a number of viable seedlings, 2 – dead and dying samples; 3 – regeneration height. Maximal observed regeneration density reach 70 thousand/ha.
Regeneration distribution along the altitudinal gradient.

Age groups: 1 - (0 – 1), 2 - (2-5), 3 – (6-10 yr); 4 - (11-15), 5 – (16-30); 6 – envelope curve for all age groups.
Landsat-derived maps of temporal changes in forest-tundra ecotone: 1976 yr (left) versus 2000 yr (right).

1 - Siberian pine prostrates and regeneration;
2 - “dark-needle” conifers (crown closure <0.3);
3 - “dark-needle” conifers (crown closure >0.3);
4 - bush-grass communities;
5 - mineralized surfaces;
6 - water bodies.
GIS-based analysis of vegetation area increments (2000 yr versus 1976 yr) with respect to azimuth: the most significant changes happened on the south-faced slopes.

1 - Siberian pine prostrates and regeneration;
2 - “dark-needle” conifers (crown closure <0.3);
3 - “dark-needle” conifers (crown closure >0.3);
4 - bush-grass communities;
5 – the base line.
GIS based analysis of vegetation area increment with respect to altitude above s.l.

1 - Siberian pine prostrates and regeneration;
2 - “dark-needle” conifers (crown closure < 0.3);
3 - “dark-needle” conifers (crown closure > 0.3);
4 - bush-grass communities.
A broader view:

Changes on the opposite side of boreal forests: northern forest-tundra ecotone

The Ary-Mas stand
On the world’s northward tree stand (Ary-Mas) during last three decades of 20th century it was observed the stand closure increase (~65%), and larch propagation into tundra (with a rate of 3-10 m/yr).

1 – background, 2 - sparse stands, 3 – closed stands.
A broader view:
Climate - driven Siberian pine (plus spruce and fir) migration to the zone of larch dominance

A – overstory, B – regeneration, C – propagation coefficient
1 – larch, 2 – Siberian pine, 3 – spruce + fir
Summary.
During last decades the following phenomena are observing in Siberian South Mountains.
1. Larch and Siberian pine are propagating into mountain tundra. This species surpass its historical tree line boundary on 30-200 m (depending on site).
2. Regeneration is climbing up along an altitude gradient with a speed of 3...5 m/yr. Temperature rise on 1°C allows regeneration to advance ~150 m.
3. Tree stands density is increasing. Closed stands “propagate” along the vertical gradient with a speed of ~ 1.0 m/yr.
4. A strong increase of apical and radial increment of larch and Siberian pine is observing since the middle of the 1980s.
5. Prostrate forms of larch and Siberian pine are turning into arboreal form.
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СПАСИБО!
THANK YOU!