INTRODUCTION

The twentieth-century migration of alpine treelines to higher elevations is attributed to the ongoing global change in Fennoscandia. The aim of this paper is to study the pattern and dynamics of the treeline advance to higher elevations on Lommolunturi fell in Finnish Lapland by analysing a time series of aerial photographs with modern image interpretation techniques and verifying the results with dendrochronological methods.

MATERIALS AND METHODS

An automated Feature Extraction Module implemented in ENVI image interpretation software (ITTVIS, Boulder, U.S.A) is used to extract the tree crowns from a digitized and georectified panchromatic aerial photograph acquired in 1947 and a false colour aerial photograph from 2003. The two step feature extraction process included segmentation and feature classification with support vector machines including textural, spatial and spectral channels of the aerial photographs as inputs. The changes in the relative crown areas of Norway spruce (Picea abies) and downy birch (Betula pubescens) were then assessed in a GIS analysis within 20 m grids, and verified with field measured forest inventory and tree-ring age data from drilled core samples. The thickness of snow pack was measured with a ground penetrating radar.

RESULTS

Change detection analysis of the tree species specific crown coverages revealed over 100 m shift of spruce trees (460 m – 530 m a.s.l) and a 40 to 60 m shift of birch (480 m – 510 m a.s.l). Based on the field data, pine has reached the top of the fell (550 m), and the treeline for birch at 510 m a.s.l. and for spruce at 510 m.

A decrease in birch canopy coverage within the forest has occurred since 1947. The individual trees which were detectable in aerial photographs have migrated 40–60 m onto the tundra. In terms of elevation, a shift from 480 m to 510 m a.s.l occurred. The highest birch densities were in the transition between forest and tundra (1500 saplings/ha).

Positive change of spruce canopy in forest indicates an invasion of conifers replacing birch from 1947 to 2003. The shades of blue are dominant indicating decrease in birch canopy coverage with in the forest. Downy birch treeline has advanced approximately 40–60 m in distance onto the tundra. The field data from downy birch (>1.3 m height) density is overlaid as symbols.

DISCUSSION

The recruitment of Norway spruce was consistent within the forest-tundra ecotone signifying the upward advance pattern. The estimated shift of 100 m (Fig. 2b) within less than 60 years may be more intensive than reported earlier. In accordance with the birch-pine-spruce succession concept, we found the replacement of birch by spruce in the forest.

The patchy pattern of the tree advance is possibly attributed to snow accumulation in bedrock fractures and troughs in the tundra; creating 'safe sites' for the advance of tree species to higher elevations. We contend that the patchy pattern of krummholz islands and 'ribbon trees' in the transition zone are due to winter wind-climate and spatial variability in snow cover. Increasing shrub cover, in terms of high rate of birch generation at the transition zone, can also result in greater snow accumulation and higher soil temperature and microbial activity in winter, which may then promote tree establishment at present.

The age structure of conifers, the youngest individuals being located at the transition zone and tundra, also demonstrates the advance of species lines and treelines to higher elevations. The oldest spruce was 185 years of age at 462 m and pine 86 years at 478 m.

The tree advance due to snow accumulation in bedrock fractures and troughs in the tundra which create 'safe sites' for advance of tree species to higher elevations.

Western winds and snow ablation challenge 'ribbon trees' on the fell.

Relative change in downy birch tree crown coverage from 1947 to 2003. The shades of blue are dominant indicating decrease in birch canopy coverage with in the forest. Downy birch treeline has advanced approximately 40–60 m in distance onto the tundra. The field data from downy birch (>1.3 m height) density is overlaid as symbols.

The yellow-orange overrules the other colours suggesting an increase in spruce canopy between 1947 and 2003. In distance, an average of 100 m upward shift of Norway spruce individuals which are visible in aerial photographs. The field data of downy birch sapling (<1.3 m height) density is overlaid as symbols.

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