Assessing the link between forest composition and soil nutrient availability in contrasting forest plots on the Kamchatka peninsula

By
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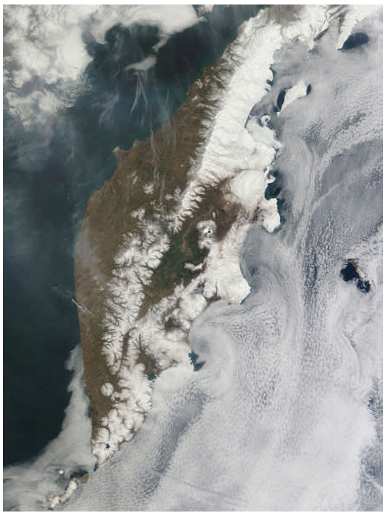

Figure 1. The Kamchatka peninsula East Russia from space (Wikiimages).

Introduction

With the ever increasing threat of global climate change, concern is growing about the consequence of large scale biodiversity losses. At present biodiversity is declining a thousand times faster than at rates found in the fossil record (Millennium ecosystem assessment 2005). The loss of species within ecosystems has the potential to impair ecosystem function as well as the systems ability to sustain life. It is therefore important to understand the interactions between ecosystem functioning and the species present, in order to assess the effects of species loss.

Nutrient cycling is the key process for carbon and nutrient flow in ecosystems. It determines the nutrient availability to plants, which the plants can then influence by alterations in root exudates or changes in growth, increasing litter input or nutrient uptake. Nutrient cycling and the plant species assemblage, form a positive feedback loop which helps to sustain the nutrient status of the ecosystem. The chemical composition of litter therefore has the potential to alter soil pH, soil organic matter (SOM) and nutrient availability influencing soil microbial communities, vital to the whole process. Litter from more productive and or diverse forest assemblages ensures a more diverse microbial community and therefore more efficient nutrient cycling.

The Kamchatka peninsula in Far East Russia makes up the northern portion of the Pacific ring of fire – a volcanic region at the interface of the Pacific and Eurasian continental plates. It lies between the Pacific Ocean and the Sea of Okhotsk, giving it a milder and wetter climate than other boreal zones. It is a unique and understudied wilderness with a highly diverse geology and topography. Forests occupy 88% of the total land area and are dominated by White Birch and Cajanderi larch trees. Frequent forest fires cause much of the forest to be patchy with areas at very different stages of recovery. The fire and volcanic debris can affect soil fertility as ash layers become incorporated within the soil.

This study assesses the links between forest assemblage, the soil nutrient availability and microbial status. Plots with more trees and a greater range of species should have greater nutrient concentrations and a larger microbial community, due to increased productivity, functional diversity and litter entering the soil. Predominantly deciduous plots would be expected to have greater microbial populations and faster rates of nutrient cycling as leaf litter breaks down more readily than that of coniferous forest.

Material & Methods

This study was carried out in conjunction with Dr Markus Eichhorn of the School of Biology. In August 2008 Dr Eichhorn carried out an expedition to the boreal forests of the Kamchatka peninsula. Here he undertook an in depth spatial structuring study of the forest and collected soil samples for analysis. This field work provided the detailed canopy and species data to which soil information could be compared.

Forest Assemblage

Eight plots in Kamchatka were chosen by Dr Eichhorn, to represent the boreal forest at different altitudes and forest compositions.

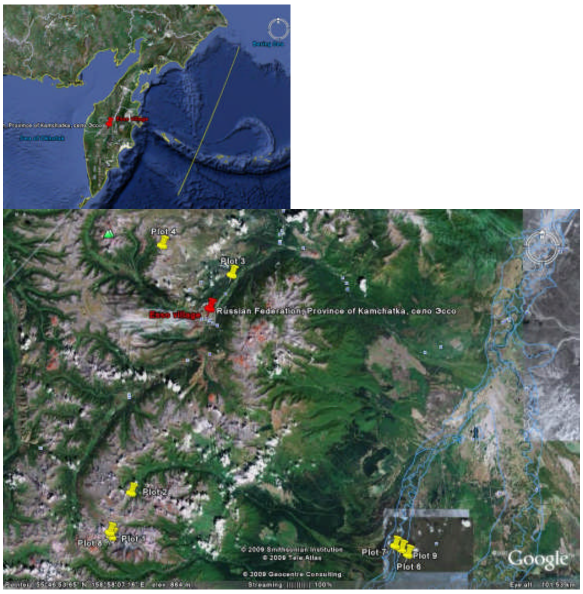

Figure 2: Google earth image of the study area.

Sampling at each of the 8 sites was carried out in an area of 50 x 50m. For each; tree species the position and number was recorded. For each individual tree the basal area was calculated from the diameter at chest height to give a measure of stand density.

Below are images of the different forest types studied.

Figure 3: White birch *Betula platyphylla* first coloniser after fire.

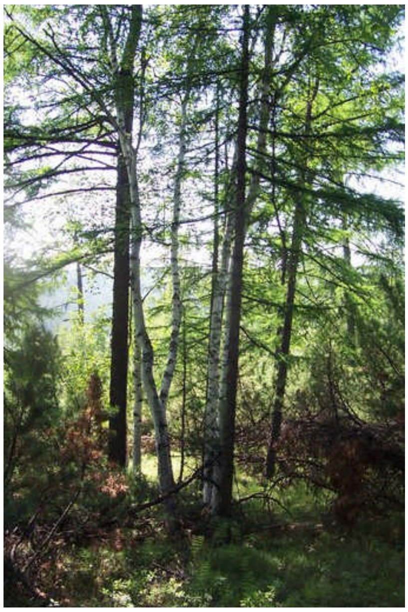

Figure 4: Mixed stands of Cajanderi larch and White birch, with Siberian dwarf pine in the subcanopy *Pinus pumila.* Larch grows up through the birch and takes over.

Figure 5: Cajanderi larch forest, *Larix cajanderi.* Larger more mature trees on the lower ground, more pine in the subcanopy on slopes.

Figure 6: Stone Birch *Betula ermanii* forest found on upland slopes more open than the others with a more highly diverse understory.

Plot	Tree species	Subcanopy	Understory
1	Stone birch upland forest.	Some Dwarf pine	Dense and diverse
2	Cajanderi larch some White birch upland forest.	Dense Dwarf Pine	Limited
3 / 4	Mixed Cajanderi larch - White birch on a ridge.	Dense Dwarf Pine some Alder	Limited
6 / 9	White birch lowland forest	None	Dense and diverse
7	Mixed Cajanderi larch – White birch lowland forest	Some Dwarf pine	limited
8	White birch – willow upland forest	Some Dwarf pine	Dense and diverse

Table 1: site descriptions

Soil Analysis

At each of the 8 plots soil was collected from the centre of 6 subplots. Prior to soil sampling the sites were cleared of all vegetation and dead leaves. A corer was used to extract the soil which was then transported back to Nottingham for analysis. Spectrophotometry was used to measure the concentration of nitrate, ammonium, phosphate and microbial mass, the latter by measuring total organic carbon and nitrogen. Soil respiration was determined using an infra red gas analyser which gives a rate of CO2 flux from the soil in $gCO_2\ m^{-2}\ hr^{-1}$.

Results

Forest Assemblage

Tree abundance and basal area was assessed in each plot. Where present the coniferous larch (*L.cajanderi)* forms the more mature forest with greater basal areas. They also dominate the canopy even if the deciduous birch (*B.platyphylla)* is more numerous. In general, basal area per hectare appeared to be higher in the lowland areas, plots 6, 7 and 9 and reduced in the upland plots 2, 3 and 8 especially where the up slope gradient was steep.

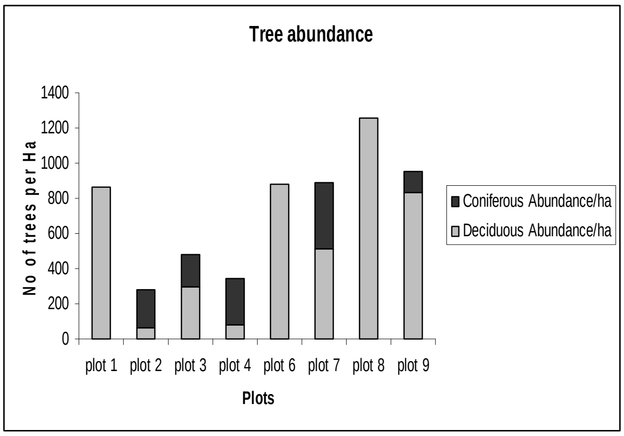

Figure 7: Bar chart of tree abundance

Plots 2, 3 and 7 were the most species rich showing a mixture in coniferous and deciduous species however in comparison to other forests diversity is low, with only 4 species as the maximum in plot 3. Within several of the plots, Dwarf pine made up a significant subcanopy more commonly beneath larch.

Overall the number of tree species was very low. Where deciduous basal area was higher, species number was lower suggesting that deciduous plots have lower tree diversity. The presence of deciduous trees appears to dominate, suppressing tree diversity.

There was a trend towards increased subcanopy cover and increased tree species richness. Dwarf pine was present in the plots with the higher tree species richness. Dwarf pine also reduced understory diversity with only shade tolerants such as mountain cranberry and crowberry adapted to low nutrient environments. Beneath the deciduous Birch woodlands without a Dwarf pine subcanopy (plots 1, 6 and 9) the understory showed a higher diversity.

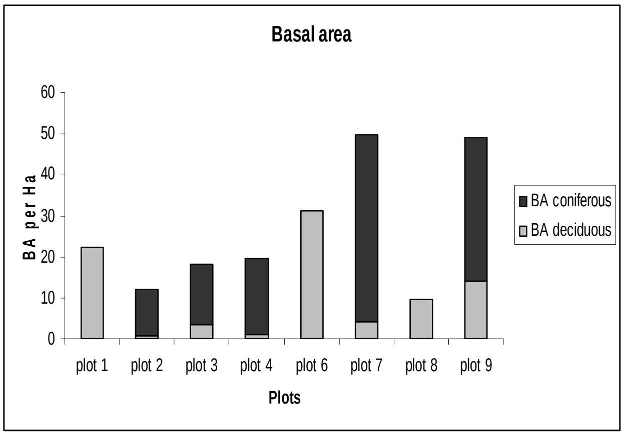

Figure 8: Bar chart of basal area (Ba).

To assess the physical effects of the environment on the forest, regression analysis was carried out to compare altitude with basal area. At higher altitudes the total basal area was lower, indicating a reduction in tree size and therefore productivity with altitude. In contrast, there was no correlation between tree species and altitude, suggesting something other than the physical position of the plot is driving the tree assemblage.

Soil Analysis

To assess nutrient availability the concentration of nitrate, ammonium and phosphate was measured in soil at each plot. No one plot was rich in all 3 macronutrients. Plot 6, lowland birch forest, showed the highest nitrate and ammonium concentrations followed by plot 1, upland birch (*B.ermanii*). Phosphate was highest in plot 7 and 9, lowland mixed forest.

Microbial biomass and nitrogen indicate the rate of nutrient cycling. Larger microbial communities tend to have faster rates of nutrient cycling. Greatest biomass was found in a mix of different forest types at different altitudes. Hence, no clear trend appeared related to altitude.

To further assess the activity of the microbial community soil respiration was also measured. Soil respiration was highest in plots 6 and 8.

Correlations between Soil Nutrient concentrations and the Tree Assemblage

Regression analysis was used to determine correlations between soil nutrients and tree composition.

A number of positive correlations became evident from the analysis:

1) An increase of deciduous basal area with nitrate,
2) A higher concentration of ammonium in the plots with a higher ratio of deciduous trees,

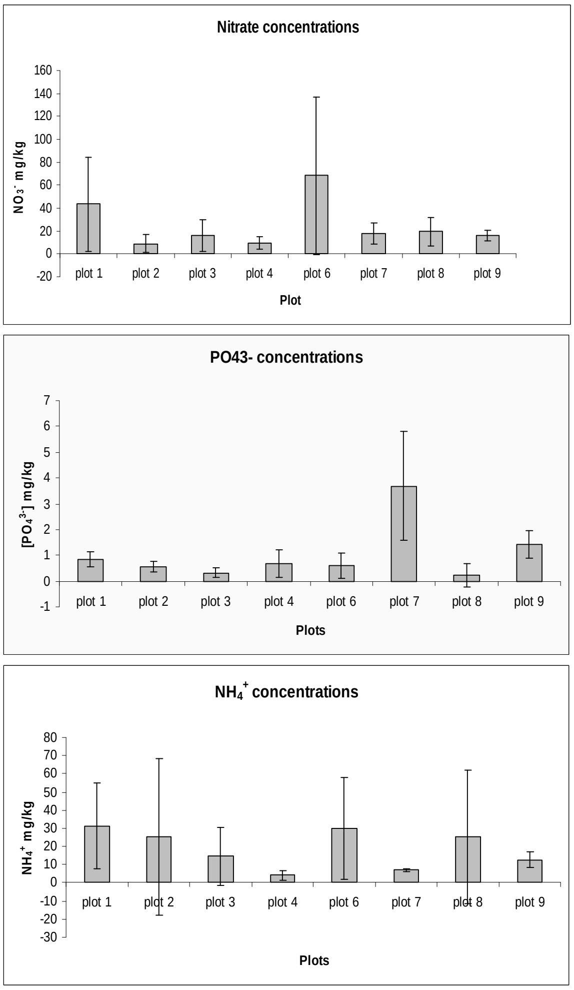

Figure 9: Bar charts of nutrient concentration nitrate, phosphate and ammonium.

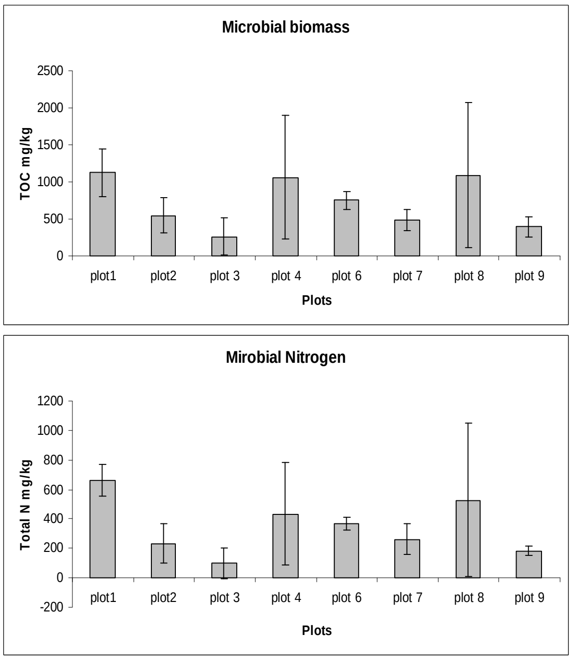

Figure 10: microbial biomass C and N.

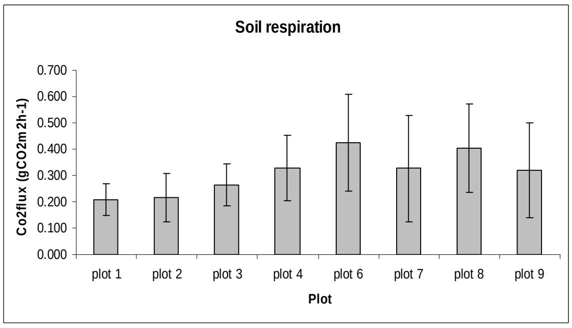

Figure 11: Soil respiration rates.

3) An increase in phosphate concentration with increased coniferous basal area,
4) Species richness causing a decrease in microbial biomass and microbial nitrogen.
5) Soil respiration demonstrated an increase with tree abundance particularly mature trees.

Discussion

This study has considered the links between forest assemblage, and the soil nutrient availability and microbial status.
The most abundant plots were 1, 6, and 8, which have a much higher proportion of deciduous trees within the plot and low sub-canopy cover. Although lower in tree species richness, these plots have higher soil nitrogen concentrations, microbial biomass and soil respiration, all of which indicates faster nutrient cycling. Coniferous plots are generally older stands, producing higher proportions of less decomposable litter (containing greater lignin) which affects microbial communities and leads to less rapid nutrient cycling (Brais et al 1995).
The presence of a substantial sub-canopy was expected to affect the species richness. Coniferous plots were less diverse than deciduous due to the suppression of Dwarf pine. Okuda & Sumida (2008) suggest Dwarf pine growth is inhibited by larch which aids the succession to coniferous forest by a reduction in nutrient availability. Altitude did not affect the tree assemblage.

Ecosystems with a fire regime tend toward deciduous pioneer species followed by coniferous. This produces a mixture of patches at different stages of development. In general the plots with a higher proportion of deciduous trees had higher nitrate and ammonium concentrations; this tends to drive greater microbial biomass and microbial nitrogen.

Nitrate concentration declined with increased coniferous abundance and subcanopy cover. Wardle & Ghani (1995) agree with this finding suggesting forest floors beneath deciduous forest stands are commonly found to be richer in nutrients related to a higher fungal biomass.
On the other hand, phosphate concentrations increase with coniferous abundance. This may be due to weathering rates, and fungi fixing greater proportions of phosphate under the coniferous stand. However, further research into the soil mineralogy and topography of the area is necessary to understand this trend.

Similarly, it was thought the more species rich plots would show greater microbial biomass. The opposite occurred with species richness causing a decrease in microbial biomass and microbial nitrogen. However the species richness measure masks species type and the presence of a subcanopy. The 3 plots with highest species richness contained a larger proportion of the Larch than other plots and a greater cover of Dwarf pine, causing an increase in more recalcitrant litter high in lignin and low in N, both suppressing microbial populations.

Soil respiration showed an increase with tree abundance particularly mature trees, possibly due to greater levels of litter, the build up of organic material and root exudates, which fuel the microbial communities.

Conclusions

This investigation suggests there are significant differences in soil nutrient dynamics between areas of forest with different vegetation compositions. The ratio of coniferous to deciduous trees was a key driver to soil nutrient concentrations, probably due to the differences in leaf litter chemical composition and quantity. This directly affects the microbial community. It was clear that predominantly deciduous forests had a significantly larger microbial biomass.
It was also observed that an increase in tree abundance leads to greater soil respiration i.e. raised microbial activity.

It is clear that there are important links between trees and soil nutrient availability in Kamchatkan forests. In further studies it would be interesting to use understory diversity and overall species richness to assess if diversity itself does have an impact on nutrient availability, compared to the dominant tree. It would be better to obtain overall soil nutrient profiles with total C, N and P and mineralisation rates.

The effects of global warming are likely to change the species profile over time. Thus, it would be interesting to monitor tree assemblage and nutrient cycling over several years.

Further Reading

Dr Marcus Eichhorns' expedition website, image source.
www.kamchatka2008.org.uk

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Author Profile

Harriet is 22 years old. After a gap year spent carrying out conservation work in southern Africa she studied BSc Environmental Science in the School of Biosciences, graduating in 2009 with first class honours. Harriet was particularly interested in landscape ecology and conservation. She is working as a scientific officer for an environmental consultancy involved with sustainable crop management.