Forest soil in European Russia: biotic and anthropogenic factors in pedogenesis

Maxim Bobrovsky

Institute of Physicochemical and Biological Problems of Soil Sciences of Russian Academy of Science
Pushchino (Russia)

Схема сукцессии после распашки при долговременном развитии леса
The scheme of succession after plowing and long term development of forest ecosystem
Study areas

Forest selection:
Forest inventory data
Remote sensing data

Objects of the investigation

Vegetation
Soil
Pedofauna
Study areas – boreal forests

All areas are situated in the taiga, in the hard-accessible parts of forestry enterprises located in:

- **Karelia republic**: Vodlozersly Leshoz, Kostomukshsky Reserve
- **Komi republic**: Pechoro-Ilychskij Reserve, Udorskij, Priluzskij and Koigorodokskij Leshozes
- **Perm region**: Visherskij Reserve
- **Kostroma region**: Mezhevskij, Paviskij and Vokhomskij Leshozes
- **Vologda region**: Andomsky Leshoz, National park ‘Russkij sever’

Main objects of the investigation

**Old-growth spruce and spruce-fir forests**

age of spruce ranged from 150 to 400 years old

**Different forest types:**

domination in ground vegetation
- dwarf shrubs and green mosses
- small herbs and ferns
- tall herbs and ferns
### Study areas – subboreal and temperate forests

<table>
<thead>
<tr>
<th>Region</th>
<th>Study Areas</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kaluga region</td>
<td>Reserve ‘Kaluzskie zaseki’</td>
</tr>
<tr>
<td></td>
<td>National Park ‘Ugra’</td>
</tr>
<tr>
<td>Voronez region</td>
<td>Reserve ‘Voronezsky’</td>
</tr>
<tr>
<td>Tambov region</td>
<td>Reserve ‘Voroninsky’ Perkinsky forest</td>
</tr>
<tr>
<td>Moscow region</td>
<td>Reserve “Prioksko-terrasny”</td>
</tr>
<tr>
<td>Tver region</td>
<td>Central forest reserve</td>
</tr>
</tbody>
</table>

### Objects of the investigation

**Old-growth broad-leaved (hardwood) forests**

Age of oak ranged from 150 to 400 years old.

**Different types of**

- Softwood (birch, aspen) forests
- Coniferous (spruce, pine) forests
Results

More than 4000 vegetation relevés

Morphological analysis of more than 1000 soil profiles (depth 1.5-3 m)

Historical/archival data for key regions

Традиционное природопользование

Рубки
Подсечно-огневое земледелие
Пожары (выжигание)
Пашенное земледелие
Сбор подстилки
Выпас
Historical land-use impacts

- Felling
- Ploughing
- Slash-and-burn
- Litter harvesting
- Grazing

Традиционное природопользование

- Выпас
  Преобладание лесного выпаса

Лицевой свод, XVI в. Москва
The Gospel, XI с. Paris
XVIII в. Москва
**Historical land-use impacts**

- **Stock-breeding**
  - Forest grazing prevailed

- **Licevoj svod, XVI c. Moscow**

- **The Gospel, XI c. Paris**

- **Miniature, XVIII c. Moscow**

---

**Традиционное природопользование**

- **Рубки, сбор хвороста**

- **Carpet, XI c.**

- **Engraving by Kallo, 1620. France**
Historical land-use impacts

- Felling, brushwood harvesting

Традиционное природопользование

- Сбор подстилки
- Сенокошение ... и др.

“Лекарство душевное”, XVII в. Москва

“Деревенское зеркало”, 1798, Тула

Большинство воздействий связаны с традиционными системами земледелия
Historical land-use impacts

- Branches, litter harvesting
- Mowing ... etc.

The important part of impacts was connected with historical agriculture systems.

Традиционные системы земледелия

- Подсечно-огневая
- Переложная
- Трехполье (вариант паровой системы)
Traditional agriculture systems

- Slash-and-burn system
- Shifting agriculture (forest-shifting system)
- Three-field system (type of fallow system)

Хронология традиционного природопользования для территории центральной России

<table>
<thead>
<tr>
<th>Рубки</th>
<th>Сбор лесной подстилки</th>
<th>Лесной выпас</th>
<th>Переложное земледелие</th>
<th>Паровое земледелие</th>
<th>Подсечно-огневое земледелие</th>
</tr>
</thead>
</table>
Macromorphological analysis of soil

What is the soil macromorphological structure?

- that we can see without special instruments

What do we see in a soil profile?

- Homogeneous elements = morphones
- Complex / Combination of elements = soil pattern
Macromorphological analysis of soil

- A soil profile is a pattern of different morphones
- The morphones are formed in result of natural and anthropogenic impacts on the ecosystem
- Sequence and strength of the impacts can be distinguished by the analysis of soil matter filled the morphones of different age

Processes of morphones forming

- Aggregation (above all biogenic aggregation)
  - Humus formation
  - Humus accumulation
- Aggregates destruction
- Regrouping
  - Pedoturbation

morphones – soil pattern/horizons – profile
Factors of morphones formation

Biotic factors
- Pedofauna activity
- Roots growth/death
- Tree-fall with uprooting

Antropogenic factors
- Fire (slash-burn, burn, artificial fires)
- Tillage
- Grazing
- Felling, brushwood harvesting
- Litter harvesting
- Mowing

Difference between traces of hardwood (A) and softwood (B) roots after wind-break or logging

A

Container
Root burrow
Stuff
Roots organic matter
Surface matter

B
Pits after tree-full is the main “depots” of the surface soil matter

Surface matter is kept mainly in peripheral parts of the pit

The main “depot” of surface matter is in a front part of pits formed after tree-full with back shifting

If we can show and make out soil morphological signs

a sequence of various impacts and their intensity may be followed up
Traces of soil macrofauna activity

Coprolites, organo-mineral aggregates

Burrows, voids

Shifted and mixed soil matter in burrows

Results of biogenic sorting of mineral matter is the immersion of stones

Pedofauna activity

It was well expressed only in forests with tall herbs domination (Schaschkov, Bobrovsky, 2008)

Brown soil with moder or mull humus dominated in tall herb spruce and spruce and fir forests
Traces of root systems in different soil horizons

- Voids in a soil after roots
- Root burrows with organic matter
- Root burrows with transformed organic matter (after mineralization, oxidation)
- Root burrows with mineral matter

Traces of root systems

Sometimes we can reconstruct:

- Tree species or species group
- Cause of tree death:
  - wind-break
  - logging
  - grubbing
  - tree-fall with uprooting
Tree-fall mosaic

Now well-expressed (occurred at different times) tree-fall mosaics attend at tall herb forests

Solitary or catastrophic tree-falls attend at other forest types

Следы ветровалов в почве

Следы западин старых вывалов в большинстве почвенных профилей во всех типах леса
Traces of tree-falls

Past ("buried") pits after tree-falls were presented

in majority soil profiles
in all soil types
in all studied forest types
Traces of past tree-fall

long stripes or cauldrons

Traces of tree-fall

Striped structure

Spotted structure («floating clods»)

Buried matters (charcoals, litter etc.)
Middle and bottom layers of soil profiles were presented by matters in pits and root burrows.

Prevailing depth of pits was between 30 and 80 sm. There were pits to 200 sm depth

There were several levels of uneven-aged pits in one soil profile (till 8 levels in trench)
Main impacts were similar in boreal, subboreal and temperate forests:

- Fire (slash-burn, burn, artificial fires)
- Tillage
- Felling
- Grazing / wood pasture

Boreal and subboreal+temperate forests differences

Boreal forests - alone major factor of human impact – **fire**
Traces of fires

Traces of fires are presented in all forest types, and they maximal in the dwarf shrub or green moss types.

Следы пожаров в почве

Формы углей

Окатанные (трансформированные на поверхности почвы)

Пластинчатые (типичные древесные угли)

Дисперсные, угольная пыль
Traces of fire - Charcoals

Charcoal forms

- rounded (transformed on the soil surface)
- lamellar (typical charry wood)
- dispersed, coal fines

Charcoal frequency

- single
- group
- layer
Charcoals in the past pits

single

“layer”

“cauldrons”

Угли в материале отсыпки вывалов

единичные

“пятно”, “котел”

«слой»
We can range different forest ecosystems by fires scale/frequency

<table>
<thead>
<tr>
<th>Traces of fires</th>
<th>Spruce and spruce-fir forest with domination</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tall herbs</td>
</tr>
<tr>
<td>Traces of fires on pine trunks</td>
<td>no</td>
</tr>
<tr>
<td>Char-coals in a soil</td>
<td>Form (shape)</td>
</tr>
<tr>
<td>Frequency</td>
<td>single or agglomeration</td>
</tr>
<tr>
<td>location</td>
<td>in past pits matter</td>
</tr>
</tbody>
</table>

Экстенсивное природопользование

= интенсивное, «на пределе», использование ресурсов без активной заботы об их возобновлении =>

=> большая площадь освоения / воздействий

Ландшафты Центральной России
Миниатюры из "Альбома Меверберга", 1661
Extensive nature management

intensive use of free goods without well care for good renewal =>
=> large area of impacts

Распашка
Plowing

The most important factor – agriculture

All present-day forest ecosystem had deforestation phases in past most often they were arable land
Старопахотный горизонт в песчаной почве
Подпахотный горизонт в суглинистой почве

Traces of tillage/plouging – in most part of soil profiles

Old-arable horizon (sandy soil)
Subarable horizon = undercrust (loamy soil)
Plows traces
Burned fertilizers matter
Soil profiles of different history

Komi republic, European Russia

without agricultural use  after agricultural use, mainly slash-and-burn

Vologda region, European Russia

without agricultural use  after long-term agricultural use, mainly shifting agriculture
Soil profiles of different history

without agricultural use  after long-term agricultural use, mainly three-field system without fertilization

Kaluga region, European Russia

Особенности воздействий на экосистемы, связанные с экстенсивным природопользованием

- разнообразие воздействий и их сочетаний
- многократность воздействий на каждый участок
- периодичность нарушений часто меньше продолжительности оборота поколений деревьев
Features of human impacts on ecosystems under extensive nature management

- Diversity of impacts and their combinations
- Multiple impacts on the same plot
- Periodicity of forest disturbances often less than the life of trees generations rotation

In soil:
Multiple alternation of soil surface transformation, illuviation, and tree-fall pedoturbations

Slash-burn cultivation and fires were the main factors of boreal soil degradation led to uncolored mineral horizon E evolution

Horizon B is mainly developed by multiple bioturbation of degraded soils and by attendant soil processes (gleyzation, mineralization, hydromorphy etc.)
<table>
<thead>
<tr>
<th>Tall herb forests</th>
<th>Dwarf shrub or green moss forests</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tree-fall mosaics</td>
<td>Low expression of tree-fall mosaics</td>
</tr>
<tr>
<td>High plant diversity</td>
<td>Low plant diversity</td>
</tr>
<tr>
<td>Many tree uprooting</td>
<td>Rarely tree uprooting</td>
</tr>
<tr>
<td>Pedofauna activity</td>
<td>Pedofauna incomplete</td>
</tr>
<tr>
<td>Moder/mull humus</td>
<td>Moor/moder humus</td>
</tr>
<tr>
<td>No E horizon</td>
<td>E horizon</td>
</tr>
</tbody>
</table>

### Comparison:

<table>
<thead>
<tr>
<th>Гар-мозаика</th>
<th>Слабо развита гар-мозаика</th>
</tr>
</thead>
<tbody>
<tr>
<td>Разновозрастные ветровалы</td>
<td>Единичные или массовые ветровалы</td>
</tr>
<tr>
<td>Высокое видовое разнообразие растений</td>
<td>Низкое видовое разнообразие растений</td>
</tr>
<tr>
<td>Активность почвенной мезофауны</td>
<td>Низкая активность почвенной мезофауны</td>
</tr>
<tr>
<td>Модер/мулль гумус</td>
<td>Мор/модер гумус</td>
</tr>
<tr>
<td>Нет подзолистого горизонта</td>
<td>Подзолистый горизонт</td>
</tr>
</tbody>
</table>

...
Long-term fire history

Long-term fire protection
Seed rains

Forest → Fire+field → Forest → Fire+field(tillage) → Pasture → Forest

Forest → Fire+field → Forest → Fire+field with fertilization → Young forest (shifting system?) → Field with fertilization → Forest → Logging → Forest → Forest
Homogeneous profile with A/H horizon is a result of long-term free development of spruce or spruce-fir forests

Thank You for Your Attention!

maxim.bobrovsky@gmail.com