Structure, Spatial and Temporal Dynamics and Mapping of the Southern Taiga -- Forests in Mid-Siberia

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Introduction

The forest ecological systems in mid-Siberia play an important role in supporting the structural carbon balance and the balance of mineral materials. These ecological systems are able to a great extent to regulate themselves and to establish a balance of substance circulation in the environment. This is particularly important in conditions of great anthropogenic forest disturbances in the south of mid-Siberia. In a number of areas of the Angara-Yenisei region the intensive damage to the forests has brought about on vast territories a formation in place of the indigenous fir-pine forests the less productive stablely-derived dark-coniferous small-leaved forests and light-coniferous small-leaved ones. This has resulted in the non-characteristic cycles of the carbon circulation. The process is connected with a disastrous change of the ecological-geographical factors and first of all with the increase of the continental features of the climate on the background of its change on a global scale.

The majority of the forests in the south of mid-Siberia are the forming ecological systems of different ages. In the forests of different ages there are different types of carbon accumulation and biological carbon circulation. While studying these forests it is especially actual to do a complex ecological – geographical research with the aim of estimating the long-lasting changes of the forests as a result of their use. With this purpose in mind it is necessary to research the spatial-temporal dynamics and , in particular, the age-regeneration dynamics and the succession dynamics of the forests and to reflect them while mapping as well as while making the multifunctional mathematical models of the carbon circulation.

We give the characteristic features of the up-to-date state and the dynamics of the forest vegetation in the south-eastern part of the Angara-Yenisey region. To prove them we give as an example a computer-made map. While mapping we used the MAGIS system. The satellite-made photos (obtained with the help of the MK-4 camera) were automatically processed.

Methodological basis and geo-informative provisions

One of the promising methods of fulfilling a given task in order to make a dynamic model of the carbon distribution among the biological components as to the main types of boreal forests in mid-Siberia is to research the forest communities and to type them on the landscape basis. In this case there is an attempt to make a transition from the phitocenotic classifications to the geographical-genetic ones. For this purpose we used the classical notions about the invariant of the geo-systems and about the genetic type of a forest. These notions are well-known in the geo-botany , in the landscape history and in the

forest history. These notions concern the research of the dynamics of forest covering (Kolesnikov 1958; Sochava 1978; Krauklis 1979; Smagin 1985; Mikheyev 1987; Smolonogov 1990; Smolonogov and Zalesov 2002). To obtain the computer-made maps the satellite-made photos were automatically processed with the help of the GIS-technologies (Konovalova and Kapralov 1997; ArcView GIS-manual. 1999; Kuzmenko and Smolonogov 2000, 2000 a, 2002; Kitov 2000; The forest vegetation 2002; Kuzmenko 2001; Kuzmenko and Smolonogov 2002 , The multifunctional adap. 2000).

The analysis of the taxonomic schemes as to the forest types in the southern taiga-forest Angara region where there are larch-pine forests and in the regions where there is a dark-coniferous taiga-forest has shown that as to the derived birch, aspen, pine forests it is not discernible in the forest-taxation descriptions that there is any connection of these forests with the indigenous ones or with the allegedly indigenous ones. Consequently there is no clear-cut spatial-ecological localisation of these forest types. The tendencies of their formation are not clear. Later on there may appear difficulties in determining the carbon cycles in the communities with the vague type of succession-temporal changes. For a number of forest types there is no differentiation as to their high-altitude positions and as to their geo-morphological complexes. In the process of making a legend to a fragment of the map of forest vegetation (the south-eastern part of the Angara-Yenisey region) the derived forests and the indigenous ones were united. The following indicators of the growing conditions were chosen: a high-altitude belt, a geo-morphological complex, a relief element, the characteristics of the soils and the moistening as well as the position (the stage) in the age-regeneration rows (Fig. 1).

To make a fragment of the map we used the topographical maps, the geo-morphological maps, the forest maps, the soil maps, the materials concerning the forestry, the taxation descriptions, the materials concerning the landscape-ecological researches and the stationary researches (Krauklis 1979; Suvorov 1980; Kalashnikov 1987). The synthesised summer colour photos obtained from the Resurs-F satellite with the help of the MK-4 camera (9 – 11m.) were automatically processed.

For the forest communities the growing conditions and the relation to the landscape are determined. While making the dynamic taxonomic legend we took into consideration the high-altitude position of the forests. There are chosen the following 4 high-altitude belts: the middle mountainous belt with the larch mountainous taiga-forests (500-600 m. above the sea level), the low mountainous belt with the southern boreal fir - Siberian-pine (and Siberian-pine – fir) taiga-forests (400-500 m. above the sea level), the high mountainous watershed belt of plains with the southern Siberian-pine – spruce - fir taiga-forests (250-400 m. above the sea level) and the taiga-complex of the river plains, of the terraces and of the slope-valley areas. In every high-altitude belt there are 4 most typical orographic complexes: 1) watersheds or a plateau and adjacent top parts of the slopes, 2) sloped relief elements, 3) sloped concave watersheds and slopes (depressions accumulating water), 4) the river valleys. There is a third group of the ecological factors. It defines the peculiarities of the ecological regime of the territory and on the whole characterises the type of the growing conditions. It is connected with the structural relief elements, the exposure of the slopes, the moistening, and the characteristics of the soils.

To study the spatial-temporal dynamics the forest communities were grouped into the successive rows of the genetic forest types, the high-altitude belt, the orographic complex, the type of the growing conditions and the age of the trees being taken into consideration. In the process of preparing the computer-made map of the forest vegetation in the south-eastern part of the Angara-Yenisei region we used a multifunctional adaptive geo-informative MAGIS system which is manufactured by the Siberian scientific–publishing and manufacturing centre of the geo-information and the applied geodesy (the Sibgeoinform centre) (The forest veg. 2002). During the first stage the map was digitised in the format A3. Then the digitised map was checked to find out weather it corresponds to the MAGIS model. It was also converted in the format HTML (the MAGIS system). And at last the MAGIS project was formed. Then a library of the conventional signs to be put on the map of the forest vegetation (1:200000) was elaborated. As well we began to form the structure of the represented information applying the qualifier of the digital information to the given fragment of the map. In the long run the computer-made map of the south-eastern part of the Angara–Yenisey region was recorded on 2 CDs using the inner format of the MAGIS system. The CDs contain as well the bases of the spatial data, the base of the semantic data, the libraries of the graphic attributes and the software. (The details of the software are given in the CD-manual.)

Subject matter and results of the research

The research of the dynamics of the forests in the landscape areas of the south-eastern part of the Angara-Yenisey region and along the Lower Angara river, the collation of the studied regions as to the way how the main forest-forming trees and the prevailing forest types spread themselves has shown that in the southern taiga-forest we can come across diverse ecological systems having the fragments of dark-coniferous, light-coniferous forests and their variants in the form of the shortly-derived, long-derived, stablely-derived birch-aspen forests. The state of the landscape structure can intensify or weaken the influence of the global tendencies in the environmental changes on the way how the dark-coniferous and light-coniferous trees take part in the forest forming process in this region.

The fragments of the maps make it clear that the structure of the forest covering is formed under the influence of the vertically organised high-altitude belts and that there are 4 levels of the spatial-functional interaction (from the mountainous, mainly larch, pine - larch, larch - pine taiga-forests in the belt of 500-600 m. above the sea level to the low mountainous fir – Siberian-pine and Siberian-pine - fir forests on the trapps in the belt of 400-500 m. above the sea level and to the forests situated on the convex watershed plains. These forests form the Siberian-pine – spruce – fir herbaceous green-moss communities. A special landscape structure is formed by the taiga-forest complex of the river valleys, the terraces and the slope-plain areas. This taiga-forest complex is characteristic of all high-altitude belts. In fact in all belts (including not shown in the fragments of the maps (the region of the village of Kazachinsky) the plain complex of the spruce – Siberian-pine - fir forests on low loamy watersheds (150-250 m. above the sea level) there are fir forests that are independent genetic forest types and that greatly differ in the structure of the types of trees, in the species diversity, in the functional features, in the natural cycles of the age-regeneration dynamics and, consequently, in the types of the accumulation

of the assimilated carbon and in the carbon biological circulation. After the anthropogenic impacts there appears a more complex picture of the temporal changes.

The collation of a fragment of the map of the forest vegetation with a fragment of the topographical map (O-46-83) (scale 1:100000) showed that for the last 40 years the area of the small-leaved forests, dark-coniferous small-leaved forests and light-coniferous small-leaved forests has increased up to 45-60 % as compared with 1953 when it was only 15-20 %. The great anthropogenic damage is characteristic of the other areas of the researched regions.

This allows us to draw a conclusion that the majority of the communities, consisting of the birch-aspen forests, are stablely-derived biogeocenoses in place of the damaged dark-coniferous forests. The analysis of a fragment of the GIS-map shows that such a transformation of the dark-coniferous forests into small-leaved ones is not only of local character but also of regional character under the influence of the changes in the landscape. Destroying the dark-coniferous forests that are a powerful forming factor of the environment brings about a sharp changing of the ecological situation. The climate becomes more continental. In spring and in early summer the air lacks moisture. It is at this time when the relative air moisture in the dark-coniferous communities is often lower than 20%. The process of the erosion and the degradation of top soils is under development. The global tendencies of the climate changes result in its warming in the northern hemisphere and in the increase of moisture in the mountains of the southern Siberia. Such warming can be traced from the 30s of the last century (Vaganov and Shiyatov and Mazepa 1996). According to V. I. Vlasenko et al. (1999) such climate changes bring about the reinforcement of fir-trees in some areas of the Eastern Sayans. It is possible that such a tendency takes place in the middle mountainous belt of the south-eastern part of the Angara-Yenisey region. In this region there are still large areas of fir forests, but nevertheless in the Lower Angara region there is no spread of the fir-trees in spite of the improvement of the climatic conditions for this type of the forest.

The structure of the forest covering is influenced very much by the endogenic factors. With the decrease in the amount of dark-coniferous forests the amount of fir-spruce seeds decreases as well, for the seeds of Siberian pines are not brought by birds any longer. The top soil is covered by turf, which results in hindering the process of the regeneration of dark-coniferous trees and in the long run there will appear “forested” meadows.

Such damages to the natural cycles of the regeneration of the fir communities and in some cases of pine communities change the structure of the redistribution of forest vegetation as well as the character of the carbon accumulation in forest ecosystems.

The conducted studies show that in a number of areas of the Lower Angara region the primary forest covering is destroyed to such a degree that, speaking about the dynamic balance between the spontaneous vegetation and the anthropogenic vegetation, we must admit that the anthropogenic vegetation prevails over the spontaneous one. There appear anthropogenic forest ecosystems as a result of a sharp change of ecological-geographical factors. And there appear a new “line” of the forest vegetation with the poor diversity as to the types of trees and with the less carbon accumulation. This forest vegetation is resistant to the recurrent anthropogenic disturbances.

The pine communities may appear in place of fire-sites in the fir forests. This process of substitution is of local character. In other words this process is not a regional regularity that perfects the biosphere function of forests or the carbon distribution among the biological components.

Conclusion

Studying the structure of the forest covering and the dynamics of this structure while mapping the forest vegetation in the south-eastern part of the Angara-Yenisei region has shown that before making the mathematical models to forecast the carbon circulation as to the main types of the boreal forests we must organise the obtained data into complex spatial-temporal cycles. These cycles must reflect the process of the formation of the most representative ecosystems that are “nuclei” for single landscapes of a different hierarchical level. The analysis of the map of the forest vegetation in the south-eastern part of the Angara-Yenisei region shows that at every high-altitude level there is an indigenous forest that is a “nucleus” for this particular belt of the forest vegetation. Accordingly for the middle mountainous belt (500-600 m. above the sea level) the “tree-soil” model must be considered using the example of the ecosystem of the larch whortleberry-lichen, whortleberry-herbaceous forest and for the convex watershed plains (250-400 m. above the sea level) - using the example of the Siberian-pine – spruce – fir, herbaceous – green-moss forest.

Adapting the models of the carbon circulation to the regional level will require a clear-cut mapping that will be able to give an idea not only about the up-to-date state of the forest vegetation, but also about the spatial-temporal dynamics of the forests, about their age structure and about the correlation between the areas as to the different types of communities.

References

Ваганов Е.А., Шиятов С. Г., Мазепа В.С. Дендроклиматические исследования в Урало-Сибирской Субарктике. - Новосибирск: Изд. Фирма СО РАН. - 1996. - 243 с.

Власенко В.И., Овчинникова Т.М., Панюшкина И.П. Динамика лесов Восточного Саяна (на примере заповедника «Столбы») // Ботанические исследования в Сибири. - Красноярск. - 1999. - Вып.7.- С. 23-72.

Калашников Е.Н. Исследование лесных ландшафтов дистанционными методами (на примере Ангаро-Енисейского региона) // Исследование лесов аэрокосмическими методами .- Новосибирск: Наука, Сиб. отд-ние, 1987. – С.10-31.

Китов А.Д. Компьютерный анализ и синтез геоизображений. - Новосибирск, 2000. – 212 с.

Колесников Б.П. Состояние советской лесной типологии и проблема генетической классификации типов леса // Изв. СО РАН СССР.- 1958.- № 2.- С.109-122.

Коновалова Н.В., Капралов Е.Г. Введение в ГИС. - М., 1997. - 159 с.

Крауклис А.А. Проблемы экспериментального ландшафтоведения. - Новосибирск: Наука, Сиб. отд-ние, 1979. – 233 с.

Кузьменко Е.И., Смолоногов Е.П. Лесные экосистемы средней и южной тайги Западно-Сибирской равнины (структура и пространственно-временная динамика).- Новосибирск: Изд-во СО РАН, Сиб. отд-ние, 2000.-218 с.

Кузьменко Е.И., Смолоногов Е.П. К характеристике современного состояния и трансформации южнотаежных лесов Ангаро-Енисейского региона (правобережье Енисея) // Труды Международного Форума по проблемам науки, техники и образования. - М. Изд-во: Академия наук о земле, 2000. - С.31-33. .

Кузьменко Е.И., Смолоногов Е.П. Современное состояние и трансформация лесов южнотаежной подзоны правобережья Енисея, их биосферная роль // География и природные ресурсы. - Иркутск. -2002. -№3. - С. – 68-76.

Лесная растительность юго-восточной части Ангаро-Енисейского региона (правобережье Енисея).- Новосибирск: 1:200000. - (Кузьменко Е.И., Улыбина Л.О.). - Новосибирск: Изд-во: Сибгеоинформ. - 2002.

Михеев В.С. Ландшафтно-географическое обеспечение комплексных проблем Сибири. – Новосибирск: Наука, 1987. –207 с.

Многофункциональная адаптируемая геоинформационная система (МАГИС32) (Руководство пользователя). –2000.

Смагин В.Н. Принципы лесорастительного районирования и классификация типов леса // Современные проблемы лесной типологии. - М.,1985.- С.44-51.

Смолоногов Е.П. Эколого-географическая дифференциация и динамика кедровых лесов Урала и Западно-Сибирской равнины. - Свердловск: УНЦ АН СССР, 1990. – 236 с.

Смолоногов Е.П., Залесов С.В. Эколого-лесоводственные основы организации и ведения хозяйства в кедровых лесах Урала и Западно-Сибирской равнины. - Екатеринбург.-2002. - 182 с.

Сочава В.Б. Введение в учение о геосистемах. - Новосибирск: Наука, Сиб. отд-ние, 1978. – 319 с.

Суворов Е.Г. Исследование антропогенных изменений геосистем Причунских ландшафтов // Изучение состояний геосистем. - Иркутск, 1980.- С.26-36.

Kuzmenko, E.I.: 2001, ‘Up-to-date State and Transformation of the South-taiga Subzone Forests of the Right Side of Yenissei Region; There Biosphere Role‘, *ESRI Library,* New-York, http: //campus. esri. com/ campus. library/ Bibliography/ RecordDetail. cfm? ID=13343.

Kuzmenko, E.I. and Smolonogov, E. P.: 2002 ‘Up-to-date state and transformation of the south taiga subzone forests’, *22 Annual ESRI International User Conference (Track: Forestry, Wildlife and Fisheries Management).* San-Diego, ESRI .- CD