## ABSTRACT

Forest decline has been going on for last decades in Europe, North America and in the Russian Far East. This process gives rise to negative ecological and economic problems. In many countries the monitoring activities have been undertaken, including surveys at national and sub-national level. A considerable number of the hypotheses have been proposed as the forest decline reasons, but neither has gained universal recognition. At first time for a main reason of the decline was taken industrial pollution of the environment, at present, however, majority of researchers are inclined to the opinion that both natural and industrial causes are to be blamed for forest decline.

Large-scale forest decline of natural Picea jezoensis and Abies nephrolepis forests in the Russian Far East has happened repeatedly and spread all over vast areas. The first reliable information about it is related to 1920s. In succeeding years forest decline was recorded in 1930s – 1940s in Primorye and in 1950s in Priamurye. Once again forest decline spread all over enormous areas of fir-spruce forests in the Sikhote-Alin during 1970s – 1980s.

The large-scale fir and spruce forest decline typical for Primorye and Priamurye was not observed in Sakhalin and Kamchatka, as well as in spruce formation in the northern areas of the Amur Region.

In this work the investigation materials of declining plots of fir-spruce forests in Primorye Territory and the main results of monitoring of fir-spruce forest decline in the basins of the rivers Svetlaya, Bol'shaya Peya and Edinka are presented. In the light of global dark-conifer forest deterioration the critical review of the previous investigation is considered.

Picea jezoensis is the principal forest-forming species of fir-spruce forests in the Russian Far East; high hydrophily and low tolerance to drought conditions characterise it; horizontal root system makes spruce strongly depending upon temperature and moisture of the soil surface layers.

Fir-spruce forest decline has occurred on various elements of relief (mountain slopes of different aspects and steepness, plateau's surfaces, over-flood plain and transitional terraces in rivers valleys) placed on the different altitude heights (from sea level to 1000 m).

The declining plots by the extent of tree destruction are divided into: diffusive-spread (single dry trees and groups of 3-5 trunks), cluster-group (groups up to 10-20 dry trees and rather small plots of continuous dead standing trees) and continuous (dead standing groups occupied hundreds and thousands of hectares). Not rare, these types reflect the successive stages that plots of decline have been passing through.

The matters for monitoring were permanent sample plots established in stands with the different stages of decline. In most cases the largest and well-developed fir and spruce trees with high calendar and ontogenetic age die off in first turn.

An age structure of the declining fir-spruce forests is characterized by uneven age. Two types of uneven aged stands are predominated: perfectly uneven aged, forming on habitats with impeded drainage, and relatively uneven aged, having originated after fires. Large dark-conifer forest areas, forming by perfectly uneven aged stands, are less suffered from the decline than even aged stands or closely related to them by structure.

As a rule, natural regeneration of dark-conifer species in the plots of decline with predominance of fir and spruce under stand canopy is satisfactory. Dying off and decomposition of stands are accompanied by diameter and height growth increment of the majority of having been surviving trees and understory. That all allows considering that the large-scale forest decline doesn't depend upon constant habitat changes to unfavourable for spruce and fir.

Soils under the declining fir-spruce forests are characterized by extremely acid soil reaction (especially humus horizons), base-exchange saturation with aluminum and hydrogen ions, in most cases unfavourable Ca/Mg ranges in the root horizons, low or extremely low content of mobile phosphorus, middle or increased mobile potassium supply, low nitrogen content, abundance of amorphous compounds of aluminum and iron, predominance of fulvic acids in the humus composition, high accumulation of zinc, nickel, cobalt and lead in the fine earth. Phosphorus and low level of soil reaction primarily limit forest growth conditions. Whereas, soil characteristics under declining forests are not differ essentially from living stands. This prevents to connect large-scale fir-spruce forest decline with the soil peculiarities.

Chemical analyses of the different organs allowed make a conclusion that the spruce has acute phosphorous deficiency. In some plots insufficient supply of spruce by nitrogen, magnesium and calcium was observed. Spruce needles are abundantly supplied with manganese and zinc, and roots with aluminum.

An investigation of chemical composition of solid precipitation in Primorye (Gladkova et al., 1993) allows concluding that the transference of industrial pollutants into the regions of growing fir-spruce forests if it takes place has occurred irregularly and it does not cause any essential changes of environment parameters. Environmental pollution is not responsible for the large-scale fir-spruce forest decline.

Analysis of weather-climatic situation during 1970-1994 is evidenced of its instability. So, on evidence of meteorological station Sosunovo, annual precipitation during that period varied from 385 mm (1978) to 1162 mm (1984), while average annual precipitation is 585 mm. Air humidity deficit also was susceptible to fluctuations. In 1972, 1978, 1985 and 1989 the beginning of vegetative season was clear droughty; air humidity deficit in May-June 1972 and 1978 was over nearly 60% in comparison with many years' duration of average amount. The unfavourable moistening conditions as a whole was during all-vegetative season of 1972 and 1978-1979.

The beginning of large-scale fir-spruce forest decline in the basin of the river Bol'shaya Peya is going back to early 1970s. In 1989 was happened a merging of isolated plots and forest decline spread all over vast territory. According to the detection of satellite images, carried out by Norihisa Kamibayashi, in 1983 area of declined forests range up to 122, in 1986 - 144, in 1989 - 189, and in 1991 - 222 $km^2$. In the basin of the river Edinka group plots of forest decline were beginning to appear in 1980, its square gradually increased but scale of the decline didn't reached size of the plots as in the basin of the river Bol'shaya Peya. The results of the repeated inspections of constant sample plots testify that forest decline is going by different rates, depending on stand condition and influence of external factors. Forest plots that have been occurred on the boundary with clear-cuttings dried during the investigation period to a greater degree; its stand practically dried. In the basin of the river Edinka declining plots had relatively stable condition.

Collected materials on large-scale forest decline in the Russian Far East undoubtedly testify that this process is developing under the influence of a complex of factors of different nature - biotic, abiotic and anthropogenic. The role of the individual factors in the forest decline is different. In this connection all the factors associated with the forest decline can be divided into causing, predisposing and accompanying (Man'ko, Gladkova, 1995). Among the factors, causing the large-scale fir-spruce forest decline in the Russian Far East should be named first of all drought

that periodically acts on the vast territory. Considering peculiarities of the main forest forming species, droughts create stress situation for stands which reaction depends on calendar and ontogenetic age. Furthermore, droughts that deteriorate stands can contribute to increase of number of defoliators and trunk pests, along with a development of fungi diseases that affect assimilative system. These factors can be related to accompanying but playing a great role in "functioning" and dynamics of declining plots.

Stress situation for dark-coniferous species was caused by influence of drought owing to sharp disturbance of water balance of trees with intensive transpiration of upper canopy, and not in cause of strong desiccation of upper soil horizons to critical values. High safekeeping of understory and its intensive growth after forest decline are demonstrated that.

Under the large-scale fir-spruce forest decline destabilization of exchange of matter and energy happens, which is expressed by a rate of turnover and volume of products, participating in this process. When intensive forest decline takes place, volley supply of dead needles occurs, and relatively high increase of other woody components (bark, knots, trunks and its parts) goes on. In relatively short period up to 500 $kg \cdot ha^{-1}$ of nitrogen and ash elements with deadwood may come to soil. The acceleration of forest litter decomposition, change of composition of lower vegetative layer, mosaic development of turf process – all of these may be considered as positive features of turnover. However, accumulation of deadwood and woody components in forest litter influenced negatively on soil condition of forest growth.

In the development of large-scale fir-spruce forest decline in the region is blamed for complex of causes as a whole, but instability of nature conditions in a transition zone from land to ocean should be taken as leading ones. Especially unfavourable are drought periods that give rise to stress situation for spruce. For the most part forest decline is developed against the background of high age of stands, which to a large degree are struck by rots and fungi diseases. These stands are rather common in the peculiar soil-hydrological conditions.

Fir-spruce forests of the Russian Far East, considering their repeated large-scale declines, are presented a matter of the economic hazard. Existence of vast areas of nature and virgin forests, which prevailing generation has a high calendar and ontogenetic age, do not eliminates the possibility of new large-scale decline in future under the influence of severe stress factors. Because of this, fir-spruce forests ought to

be into the constant view of foresters. First and foremost forest-managing efforts must be directed on predisposing factors: reduction of the proportion of mature and over-mature stands in structure of forests, formation of mixed stands, maintaining of multi-age of stands, selection of spruce tolerant to stress situation.

Deterioration of dark-conifer forest condition and their decline has been going on different continents. Spruce species of different ecology, which above all variously disposed to warmth and moisture, are susceptible to decline. Hand in hand with moisture-loving and relatively warmth-loving species (Picea rubens, P. sitchensis) dies moisture loving, and yet more frost-tolerant P. jezoensis as well as P. abies, which slightly higher tolerant to temperature and moisture fluctuations. P. glauca and its hybrid (P. lutzii) that characterized by wide ecological amplitude also die. Production as well as natural and virgin forests, not exhibiting direct anthropogenic influence, are susceptible to decline. Attention is drawn to the fact that dark-conifer forests subjected to decline exhibits influence of the ocean air masses. At least, natural large-scale forest decline with predominance of spruce was not noted in the typical continental areas. This allows proposing that the main cause that gives rise to large-scale forest decline is instability of weather-climatic situation in transition zone from land to ocean. This may be a result of phenomenon influence of El-Niño on atmospheric processes in boreal zone.

Large-scale forest decline of dark-conifer forests occurs not only in the zone of influence of industrial pollution, but also in the areas free of stable air contamination (Primorye, Priamyrye, Alaska); this allows to dispose to pollution as additional stress, superimposing on natural processes.

Dark-conifer forest decline gives rise to essential economic and ecological problems (loss of wood and recreation attractiveness, deterioration of sanitary and fire conditions, change of hydrological regimen of the area, acute change of the rate of exchange of matter and energy including oxygen-production and carbon-accumulation functions of forests). All of these resulted in necessity of organization of monitoring of the forests, playing remarkable role in the stabilization of global ecological situation. Forest deteriorating problem came out from national boundaries and requires co-ordination of investigations in international scale; it is possible under the aegis of IUFRO. The problem has universally biological significance as well as associated with stability of nature systems to the changeable environmental conditions and with the elucidation of causes, and prediction of this phenomenon.

Included in further aims, connected with the large-scale dark-conifer forest decline, it is necessary to name: fundamental study of the main forest-forming species, looking for biochemical indicators of stress situations, searching of methods of early giving of diagnosis of stand's weakness, microbiological soil characteristics in the declining stands. Absolutely essential are integrated interdisciplinary research activities.