AGS Acta Geographica Silesiana, 11/1 (25).
WNoZ UŚ, Sosnowiec, 2017, s. 31–38

ISSN 1897–5100

УДК 630*231

Andrey N. Saltykov[1], Olena Kolchanova[2]

[1]National Park Smolensk Lakeland, 216270 Smolensk region, Demidov district, Gurevich's street 19, settlement Przhevalskoe, Russia; e-mail: saltykov.andrey.1959@mail.ru

[2]Department of Silviculture and Genetics of Forest Trees; Forest Research Institute, Braci Leśnej str. 3, Sękocin Stary, 05-090 Raszyn; e-mail: O.Kolchanova@ibles.waw.pl

SCOTS PINE NATURAL REGENERATION CYCLICITY AS THE THEORETICAL BASIS FOR THE DEVELOPMENT OF MEASURES TO SUPPORT INDIGENEOUS FORESTS REPRODUCTION

SAŁTYKOW A. N., KOŁCZANOWA O. **Cykliczność naturalnej regeneracji sosny jako teoretyczna podstawa do opracowania działań na rzecz naturalnych procesów odnowy rdzennych lasów.** Przedstawiono wyniki badań przeprowadzonych w latach 2003–2015 nad procesami naturalnej regeneracji sosny na obszarze stepowym oraz w strefie lasów iglastych, mieszanych i liściastych Rosji oraz Ukrainy. Stwierdzono cykliczność badanych procesów. Przyjęta koncepcja cykliczności naturalnego regeneracji w lasach sosnowych, uwzględnienie zasad przestrzenno-wiekowej struktury cenopopulacji podrostu oraz współczesnych doświadczeń w zakresie tworzenia stopniowych zrębów, stało się podstawą do poprawy istniejących sposobów restytucji i odnawiania rdzennych lasów sosnowych.

Салтыков А. Н., Колчанова Е. **Цикличность естественного возобновления сосны как теоретическая основа для разработки мероприятий по сопровождению процессов естественного возобновления и восстановления коренных лесов.** Результаты исследований процессов естественного возобновления сосны в условиях степной, лесостепной и зоне хвойно-широколиственных лесов России и Украины, выполненные в течение 2003–2015 гг. позволили выявить наличие цикличности в рамках изучаемого процесса. Принятие концепции цикличности естественного возобновления сосняков наряду с закономерностями пространственно-возрастной структуры ценопопуляций подроста и современным опытом выполнения постепенных рубок послужили основанием для совершенствования существующего комплекса мер по сопровождению процессов возобновления и восстановления коренных сосновых лесов.

Key words: Scots pine, understory, natural regeneration, coenopopulation, regeneration wave, shelterwood felling, forest ecosystem

Słowa kluczowe: sosna zwyczajna, podrost, naturalna regeneracja, cenopopulacja, fala regeneracji, wyręby stopniowe, ekosystem leśny

Ключевые слова: Сосна обыкновенная, подрост, естественное возобновление, ценопопуляция, волна возобновления, постепенная рубка, лесная экосистема.

Abstract

The study of Scots pine (*Pinus sylvestris*) natural regeneration in the steppe, forest steppe and mixed coniferous forest zones conducted in Russia and Ukraine in 2003–2015 revealed its cyclicity. The adaptation of the concept of pine forests natural regeneration cyclicity along with space-age structure patterns of understory coenopopulation and modern experience of shelterwood felling formed the basis for improving the existing set of measures to support the regeneration of indigenous pine forests.

INTRODUCTION

The cyclical regeneration of Scots pine (*Pinus sylvestris*) and its wave-like character in semi-arid zones has been repeatedly examined by researchers, at least as far as proposing it as a working hypothesis (DMITRIEVSKY, 1928; VRADIY, 1961; PYATNITSKY, 1964; SANNIKOV, SANNIKOVA, 1985; SALTYKOV, 2008, 2014; SINITSYN 2008). Certain stages of the process are consistent with global natural phenomena, especially with the inversion of climate indicators as contrasted with long-term average annual values. According to the researchers, a regeneration wave is influenced by the climate and conditions of the steppe and forest-steppe zones and occurs when there is precipitation greatly exceeding the average annual level (DMITRIEVSKY, 1928; VRADIY, 1961; PYATNITSKY, 1964; SANNIKOV, SANNIKOVA, 1985; SINITSYN, 2008; SALTYKOV, 2014). The variability of precipitation during the growing season is very important (SALTYKOV, 2014). Under these circumstances the successful implementation of reproductive capacity resulting in pine seedlings, and eventually in understory, is found throughout vast regions (VRADIY, 1961; PYATNITSKY, 1964; SALTYKOV, 2014; SALTYKOV, ABODONOVA, 2015). A natural regeneration boom can be looked upon as a response of the population to the change in the balance of environmental factors and in the energy balance of forest ecosystems as a whole (DMITRIEVSKY, 1928; VRADIY, 1961; PYATNITSKY, 1964; SANNIKOV, SANNIKOVA, 1985; SALTYKOV, 2014; SALTYKOV, BORISOVA, GARMASH, 2015). So the assumption can obviously be made that the regeneration boom frequency is influenced by the long-term patterns of climate variability (DMITRIEVSKY, 1928; VRADIY, 1961; PYATNITSKY, 1964; SANNIKOV, SANNIKOVA, 1985; SALTYKOV, 2014).

Discovering the cyclical process of natural regeneration is the basis for improvement of the natural regeneration theory (SANNIKOV, SANNIKOVA, 1985; SALTYKOV, 2014). From a practical standpoint, the adaptation of the regeneration cyclicity concept enables us to improve a set of measures for supporting indigenous pine forests reproduction, as well as conservation of biological diversity, genetic and population structure of forest ecosystems.

METHODS AND SCOPE OF RESEARCH

The research is based on the historical method, which allows us to recreate the time series of regeneration booms. It also involved a set of field research activities used for studying spatial and age characteristics of Scots pine understory and saplings coenopopulation structure. Besides, when developing measures to support the processes of natural regeneration, the up-to-date experience in shelterwood felling in the southern forest-steppe zone of the left-bank Ukraine was used (PYATNITSKY, 1957; SHISHKIN, 1969, 1972; SALTYKOV, TKACH, MOTOSHKOV, 2005; SALTYKOV, TKACH, POZNYAKOVA, 2006).

During 2003–2015 the study of natural regeneration processes was performed in the steppe, forest-steppe and the mixed coniferous forest zone of Russia and Ukraine. For example, the main sample plots were established in the Seversky Donets River basin. Some control plots were located in the Dnieper, Desna, Western Dvina and Oka river basins. The results obtained were used to perform a comparative analysis of the age and spatial structure of understory coenopopulation. During the twelve years of research about 600 plots were set up with the aim of studying the characteristics of the process. When studying the spatial and age structure of Scots pine understory and saplings we applied the methods developed by S. S. PYATNITSKY (1959), P. GREIG-SMITH (1967), Y. A. ZLOBIN (1976), S. N. SANNIKOV, N. S. SANNIKOVA (1985) et al., partly adapted in accordance with the purposes and objectives of the research (SALTYKOV, 2014). The data obtained were processed according to methods of mathematical statistics (DOSPEKHOV, 1965).

RESULTS

The retrospective analysis performed and the results obtained made it possible to recreate a significant fragment of the time series of regeneration booms over the past century. For the pine-forest terrace of the Seversky Donets these periods can be named: 1906–1909, 1911–1912, 1919, 1926 (25), 1931–1932, 1935–1936, 1941–1943, 1952–1953(4), 1964–1965. This list of regeneration booms was first fixed for the pine forests in the Seversky Donets River basin (SALTYKOV, 2014). Subsequently, with increased research scopes and objects the pine population flows were found to be concurrent not only in the steppe and forest-steppe, but also in mixed coniferous forest zone (SALTYKOV, ABODONOVA, 2015; SALTYKOV, ANDREEVA, 2015; SALTYKOV, VATLINA, 2015). A typical example of the population boom in the course of pyrogenic succession is shown in phot. 1.

Analyzing spatial and age characteristics of Scots pine understory and saplings coenopopulation structure provided the data necessary for completing the time series (phot. 1). For example, over the past 25–30 years in the Donets, the Dnieper, the Western Dvina and the Oka river basins at least four regeneration waves have been recorded. Dominant generation within the regeneration wave age structure is represented by individuals who sprouted in 1985–1986, 1990–1991, 1995–1996, 2002–2003, and 2007–2008. Our observations indicate that within a coenopopulation the age of the dominant generation can vary to the extent of one or two years, but the common pattern typical of the process can still be clearly traced. According to the data received, the cycle time ranges, on average, from 5 to 12 years. Using the occurrence frequency of age dominants (phot. 2) enabled us, with a degree of certainty, to recreate missing generations within the time series of the past century.

The recreated and completed list of natural regeneration booms is as follows: 1906–1909, 1911–

1912, 1919, 1926(25), 1931–1932, 1935–1936, 1943–1943, 1946–1947(8), 1952–1953(4), 1957–1958, 1964–1965, 1969–1970(71), 1976–1977, 1981–1982, 1985–1986, 1990–1991, 1995–1996, 2002–2003, 2007–2008. We do not claim absolute accuracy, but are merely making an attempt to recover information about the characteristics of the pine forests population flow in the last century within the boundaries of the examined region. According to the results, only during the period from 1906 to 2007–2008 a regeneration wave has been recorded, at least, from 18 to 20 times, and the list of waves is unlikely to be completed yet.

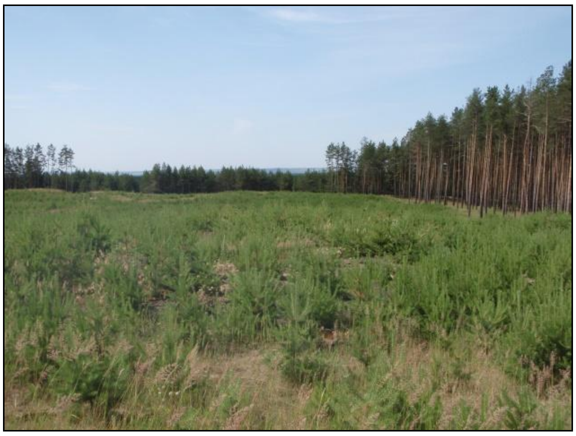

Photo 1. A typical example of the population boom in the course of pyrogenic succession. The object is situated in the steppe part of the Donets River basin (phot. by A. N. Saltykov}

Fot. 1. Typowy przykład intensywnego rozwoju populacji sosny w warunkach pirogenicznych. Obiekt badań znajduje się w stepowej części dorzecza Siewierskiego Dońca (fot. A. N. Sałtykow)

Фот. 1. Типичный образец популяционного всплеска для условий пирогенного ряда. Объект расположен в степной части бассейна С. Донца (фот.: А. Н. Салтыков)

The received results allow us to draw a preliminary conclusion that the generation flow is a time-continuous, invariable characteristic of Scots pine that enables it to hold and restore the population fields lost for various reasons. Along with constancy of the generation flow and its continuity in time, it is also characterized by discreteness, caused in the first place by dry periods when the appearance of self-seeding and its development into understory is impossible (DMITRIEVSKY, 1928; GONCHAR, 1957; VRADIY, 1961; PYATNITSKY, 1964; SHISHKIN, 1969, 1972; SANNIKOV, SANNIKOVA, 1985; SALTYKOV, 2008, 2014; SINITSYN, 2008; SALTYKOV, VATLINA, 2015). The alternation of wet and dry periods largely determines the boom and attenuation of a regeneration wave. This characteristic of a regeneration wave should be taken into consideration not only within the framework of theoretical studies,

Fig. 2. The age dominant of this plot sprouted in 2002–2003. Density of plants within the formed coenopopulations varies from one thousand to several tens of thousands plants per hectare (phot. by A. N. Saltykov)

Fot. 2. Dominanta wiekowa podrostu odnosi się do lat 2002–2003. Gęstość roślin waha się od jednego tysiąca do kilkudziesięciu tysięcy egzemplarzy na hektar (fot. A. N. Sałtykow)

Фот. 2. Доминанта возрастного спектра подроста относится к 2002–2003 гг. Густота растений в границах сформированных ценопопуляций варьирует от одной до нескольких десятков тысяч растений на гектар (фот.: А. Н. Салтыков)

but also in the forest management practice because the measures to support natural regeneration in periods of its intensification or, on the contrary, its attenuation, will bring entirely different results in terms of forestry-ecological and thus economic efficiency.

The results of the experiment using shelterwood felling in pine-forest terrace of the Donets prove that. The time of the experiment coincided with a population boom that largely determined the success of the planned event. A brief analysis of the conducted experiment allows us to say the following. In 1960–1961 the Forestry Department of the Kharkiv Agricultural Institute developed a program of natural regeneration processes study in the left-bank Ukraine and prospects for its use in agriculture (PYATNITSKIY, 1957; SALTYKOV, TKACH, MOTOSHKOV, 2005; SALTYKOV, TKACH, POZNYAKOVA, 2006; SALTYKOV, 2014). In the obligatory list of fellings to be tested and implementted, complex three-stage shelterwood fellings were included. A brief description of stands designated to be felled is presented in table 1.

At the beginning of the experiment pure mature and over-mature stands of Scots pine had a rather high volume up to 300–390 m³/ha and uneven forest density (PYATNITSKY, 1957; SALTYKOV, TKACH, MOTOSHKOV, 2005; SALTYKOV, TKACH, POZNYAKOVA, 2006; SALTYKOV, 2014). Conducting fellings and further experiments requires the presence of self-seeding and understory under the shelterwood canopy (table 2).

The Scots pine understory is found for the most part in canopy gaps and is positively related to midday shade. According to the researchers, the understory consists of several generations. For example, at the sample plots the understory aged from 2 to 7 years accounted for 60%, up to 10 years – for 90%, whereas the plants aged over 10–15 years were evidenced only rarely (Pyatnitsky, 1957; Shishkin, 1969, 1972; Saltykov, Tkach, Motoshkov, 2005; Saltykov, Tkach, Poznyakova, 2006; Saltykov, 2014). As noted by some researchers, the older the understory is, the worse its living condition is. Therefore, one of the objectives was to preserve the existing understory and create the necessary conditions for recruitment of new pine generations. Phot. 3 shows Scots pine stand formed from the understory which had existed at the plot before the experience commenced.

Both felling and tree hauling were accomplished during winter months. Technology did not provide any additional conditions except targeted tree felling.

Table 1. Silvicultural characteristics of stands to be felled
Tabela 1. Charakterystyka leśno-taksacyjna drzewostanów przeznaczonych do wyrębu
Таблица 1. Лесоводственно-таксационная характеристика насаждений, отведенных в рубку

Felling system	Cutting area (ha)	Age (years)	Forest density	Mean		Volume per acre (m³/ha)
				Diameter (cm)	Heigh t (m)	
Complex three-stage shelterwood fellings	27.5	120	0.4	40	28	300

Table 2. Amount of Scots pine self-seeding and understory on the sample plots before the felling
Tabela 2. Samosiew I podrost sosny na powierzchniach kontrolnych przed wyrębem
Таблица 2. Количество самосева и подроста сосны на опытных участках до рубки

Section	Felling system	Amount (thous. pcs./ha)		
		self-seeding	understory	total
73	Complex three-stage shelterwood fellings	16.7	4.8	21.5

Photo 3. Scots pine stand formed from the understory which built up in canopy gaps before felling (phot. by A. N. Saltykov)
Fot. 3. Sosny powstałe z podrostu, który utworzył się w oknach koron drzewostanu przed wyrębem (fot. A. N. Sałtykow)
Фот. 3. Насаждение сосны, сформировавшееся из подроста сосны, который был накоплен в „окнах" полога древостоя до рубки (фот.: А. Н. Салтыков)

Due to the decrease of self-seeding and understory in the course of felling some measures supporting regeneration have been developed. They include spring and fall tillage of the forest floor with a disc harrow. The first stage of the felling on the most sample plots was completed in 1972 and its results were found to be satisfactory. The last stage of the felling was conducted at the beginning of the 90th.

In 2005 the evaluation of the newly formed stand was continued. Our observations showed that the sample plot in section 73 has stood the test of time. The last stage of the felling there was carried out during 1991–1992 (phot. 4). In the entire area (27.5 ha) designated to be felled, the shelterwood canopy has been replaced by new generations of Scots pine (Saltykov, Tkach, Motoshkov, 2005; Saltykov, Tkach, Poznyakova, 2006; Saltykov, 2014). After performing some research, a system of sample plots has been more or less evenly placed in section 73. Sample plots have been established within units 4, 7, 8, 10, 11 and 17. In accordance with the received data, the stand is satisfactory but differs from other forest stands of the same age in its peculiar space-age structure (phot. 5). Silvicultural characteristics of this sample plot are shown in table 3.

Photo 4. In section 73 of the Skripaevsky scientific-experimental forestry of the Kharkiv Agricultural Institute (now it is Kharkiv National Agrarian University) the last stage of the felling was successfully completed in 1992 (phot. by A. N. Saltykov)

Fot. 4. Na obszarze 73 oddziału skripajewskiego szkolno-doświadczalnego gospodarstwa leśnego Narodowego Charkowskiego Uniwersytetu Rolniczego w 1992 roku pomyślnie zakończono stopniowe kombinowane wyręby (fot. A. N. Sałtykow)

Фот. 4. На территории 73 кв. Скрипаевского учебно-опытного лесхоза ХСХИ (ныне ХНАУ) в 1992 г. был успешно завершен последний прием комбинированных постепенных рубок (фот.: А. Н. Салтыков)

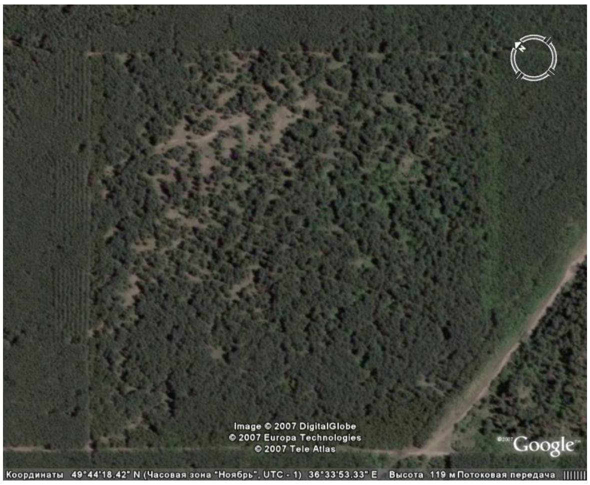

Photo 5. Pine stands formed in the course of shelterwood felling have uneven canopy closure and forest density. Glades and canopy gaps are characteristic of newly established stands

Fot. 5. Drzewostany sosnowe, powstałe w wyniku wyrębów stopniowych, cechują się nierównomierną zwartością koron. Obecność polan i okien w drzewostanie jest typową cechą nasadzeń antropogenicznych

Фот. 5. Насаждение сосны, сформированные в результате постепенной рубки, имеют неравномерную сомкнутость полога и полноту. Наличие полян и „окон” в пологе древостоя характерная черта вновь созданных насаждений

Table 3. Silvicultural characteristics of sample plots (according to the data from 2005)
Tabela 3. Taksacyjna charakterystyka powierzchni kontrolnych (wg danych z roku 2005)
Таблица 3. Таксационная характеристика опытных объектов (по данным 2005 г.)

Sample plot	Tree species composition	Mean		Age (years)	Site quality	Forest density	Volume (m³/ha)
		Diameter (cm)	Height (m)				
1	100% Scots pine	24.9	17.2	40/40	1	0.7	210
2	100% Scots pine	20.5	14.8	40/55	2	0.6	150
3	100% Scots pine	24.5	17.0	40/40	1	0.86	240
4	100% Scots pine	21.7	14.0	40/30	2	0.48	100
5	100% Scots pine	19.7	16.0	30/30	1	0.82	220
7	100% Scots pine	26.2	19.4	50/55	1	0.96	330
8	100% Scots pine	21.4	16.1	40/45	1	0.82	230

Within the newly formed stand can be traced the outlines of biological groups that either existed before the felling commenced or appeared in the course of it. Due to the clear structure of canopy, at least two types of stand can be distinguished: stand formed from the understory already existing before the felling, and understory that sprang up during complex three-stage shelterwood fellings (phot. 6). More distinct outlines are typical of pine stands sprung up in the course of the second and the third stages of the felling. Within existing and spatially separate biological groups research has also been conducted. The results are shown in table 4.

Photo 6. The second permanent sample plot. The pine stand has been formed in the course of a shelterwood felling (phot. by A. N. Saltykov)

Fot. 6. Druga stała powierzchnia kontrolna. Nasadzenia sosny jako wynik stopniowego wyrębu (fot. A. N. Sałtykow)

Фот. 6. Вторая постоянная пробная площадь. Насаждение сосны сформировано в процессе выполнения постепенной рубки (фот.: А. Н. Салтыков)

Table 4. Silvicultural characteristic of biological groups (according to the data from 2005)
Tabela 4. Taksacyjna charakterystyka biogrup (wg danych z roku 2005)
Таблица 4. Таксационная характеристика биогрупп (по данным 2005 г.)

Biological group	Area (ha)	Tree species composition	Mean		Age (years)	Site quality	Forest density	Volume (m³/ha)
			Diameter (cm)	Height (m)				
9	0.55	100% Scots pine	25	18	50	2	0.6	240
10	0.31	100% Scots pine	22	15	40	2	0.5	150
11	0.11	100% Scots pine	17	14	35	2	0.7	210

A characteristic feature of the newly formed stands is large variability of their diameter, height, density and volume (tables 3 and 4). Such heterogeneity may be attributed to the peculiarities of Scots pine natural regeneration when conducting three-stage shelterwood fellings, and to the fact that the fellings were carried out according to the usual processing method.

At present the stands are steadily growing. They have begun to bear seed and have some value because they have been formed in a natural way (SALTYKOV, TKACH, MOTOSHKOV, 2005; SALTYKOV, TKACH, POZNYAKOVA, 2006). The applying of complex three-stage shelterwood fellings in fresh subor (pine-oak forest growing on loamy sands) (phot. 7) can be regarded as quite successful and its results can be recommended for forest management.

Cyclicity of natural regeneration, space-age patterns of pine understory coenopopulation formation as well as application of shelterwood fellings provided the basis for developing regeneration supporting measures. One of the keys to regeneration support is stage monitoring, each stage providing a solution of a specific task.

At the **first stage** the amount of annual precipitation and precipitation during the growing season are monitored. A marker and information base crucial for this stage is a significant rise in precipitation as compared to long-time average annual, especially if it has been recorded for two or three consecutive monito-

Photo 7. Typical fresh oak-pine subor (phot. by A. N. Saltykov)

Fot. 7. Typowe zbiorowisko dębowo-sosnowe (fot. A. N. Sałtykow)

Фот. 7. Типичная свежая дубово-сосновая суборь (фот.: А. Н. Салтыков)

red. A marker and information base crucial for this stage is a significant rise in precipitation as compared to long-time average annual, especially if it has been recorded for two or three consecutive years. At the same time the seed bearing of the pine forest is to be monitored. The information received enables foresters to become aware of increased numbers of seeds coming under shelterwood canopy. Such data is easy to gain since it is stored at the level of forest enterprises and regional forest-seed bases. Coinciding of at least two phenomena – increase in precipitation and increased seed-bearing – provides the basis for moving on to the next monitoring stage – the local.

The main objective at the **second stage** is to critically analyze primary evaluation data on activation of pine regeneration. The monitoring is conducted at the level of forest enterprises. Research requires locating the objects and determining their silvicultural characteristics. Within the sample plot the presence of self-seeding is determined and its condition is evaluated. First of all the mature and over-mature stands should be examined because it is there that self-seeding is likely to appear. The sites passed by fire during the last two or three years should also be examined. The main objective at this stage is to locate the plots with dense self-seeding. Lands which are not any longer used as farming sites should also be examined. Areas revealing Scots pine self-seeding are to be mapped, and their characteristics, namely density, condition, and spatial peculiarities of the coenopopulation or its fragments are to be registered. The mapping completed a list of regeneration sites providing data on area and density should be made. This stage also involves uploading the data on sample plots into GIS.

At the **third stage**, namely when the pine saplings are two years old, their quality and quantity are to be evaluated. It is necessary for further differentiation of sample plots and the selection of the most promising plots. Within each plot a system of sites is to be established and understory quantity and condition are to be evaluated. The gathered data provide a basis for deciding whether the monitoring should be finished or carried on. To the evaluation should be added an updated map of the sample plots with spatial boundaries of the coenopopulation or its fragments. According to the second year evaluation all sample plots are divided into two categories: plots with self-seeding and understory under the shelterwood canopy, and plots with self-seeding outside of the shelterwood. For the stands with a significant amount of sustainable self-seeding and understory a system of fellings is develo- 2. ped. It includes shelterwood fellings, group selection fellings, and complex fellings, which should provide the necessary capacity of the ecological niche for further successful growth of understory, and formation of a sustainable pine coenopopulation. In each case the type and method of felling should be chosen according to the condition of understory, its spatial configuration, and density. The understory outside of or along the outer boundary of the stand is to be evaluated as well. The minimum inventory item of such areas is 0.5–1.0 ha.

At the **fourth stage**, as soon as the understory reaches the age of three or four years, a new inventory of the coenopopulation and update of its spatial configuration is conducted. According to this inventory, GIS information is updated. Based on the inventory and evaluation some recommendations are developed as far as implementation of the understory in forest management is concerned. The prospects of sample plots management considering natural regeneration are defined.

The objective at the **fifth stage** is a systemic evaluation of the coenopopulation condition and prospects. At this stage evaluation is carried out every two or three years until the stand reaches the age of ten years or until the forest canopy closes and a common boundary of the coenopopulation is formed. At the same time the part of the area free of pine saplings or understory is identified, and a decision concerning improvement of the coenopopulation spatial configuration is made.

When conducting evaluation and inventory, not only the quantity and age of the understory should be analyzed, but its condition as well. It enables foresters to define the short-term prospects of coenopopulation. The evaluation of coenopopulation and identification of its type (prosperous, balanced or depressed) provides the basis for developing principle measures to support the understory or giving these measures up because of their inexpediency. Consequently, it allows foresters to estimate the level of necessary costs. The ranking of regeneration sites in each case is made according to the size of understory area, its condition, and near-term prospects of usage.

Thus, all the measures to support regeneration processes can be divided into five stages:

1. Monitoring of weather conditions and Scots pine seed-bearing in the research area.
2. Monitoring of the regeneration boom at the regional and local levels.
3. Compilation of spatial localization data on regenerating sites and their subsequent differentiation, considering their peculiarities and use objectives of newly formed understory coenopopulations.
4. Development and implementation of measures to support the regeneration in accordance with the condition of the coenopopulation.
5. Systemic evaluation of condition and prospects of the coenopopulation until the site develops into a forest covered area.

CONCLUSION

The adaptation of the regeneration cyclicity concept makes it possible to improve measures supporting indigenous pine forests reproduction as well as conservation of biological diversity, genetic and population structure of forest ecosystems. One of the main conditions for regeneration support is monitoring of every implementation stage which enables the researcher to update the scope of monitoring and evaluate the short-term prospective usage of the understory coenopopulation in the forest management.

REFERENCES

Dmitrievsky P. I., 1928: K voprosu o vozobnovlenii sosnovykh lesov estestvennym podrostom. Vesti KhSHI, 10: 1–19.

Dospekhov B. A., 1965: Metodika polevogo opyta. Kolos, Moskva: 423 p.

Gonchar M. T., 1957: Biologicheskie gruppy podrosta v sosnovykh lesakh yuga lesostepi. Zapiski KhSHI, XVI: 117–133.

Greig-Smith P., 1967: Kolichestvennaya ekologia rastenii. Mir, Moskva: 358 p.

Pyatnitsky S. S., 1957: K istorii lesnogo fakul'teta Khar'kovskogo sel'skohozyaystvennogo instituta im. V. V. Dokuchaeva. Zapiski KhSHI, XVI: 3–9.

Pyatnitsky S. S., 1959: Metodika issledovanii estestvennogo semennogo vozobnovlenia v lesakh levoberezhnoi Lesostepi Ukrainy. Khar'kov: 18–26.

Pyatnitsky S. S., 1964: Lesovozobnovlenie v usloviyakh levoberezhnoi Lesostepi USSR. Lesorazvedenie i vozobnovlenie: nauch. tr., t. XLV. Kiev: 3–23.

Saltykov A. N., 2008: Avtoregulyaciya prostranstvenno-vozrastnoi struktury volny vozobnovlenia na garel'nikakh. Lesovodstvo i agrolesomelioraciya. UkrNILHA, 114. Khar'kov: 90–95.

Saltykov A. N., 2014: Strukturno-funkcional'nye osobennosti estestvennogo vozobnovlenia pridoneckikh borov. KhNAU, Khar'kov: 361 p.

Saltykov A. N., Abodonova M. N., 2015: Sinkhronnost' processov vozobnovlenia sosny v Evropeiskoi chasti Rossii i Ukraine. Materialy nauchnoi konferencii „Lesnaya nauka v kontekste ustoichivogo razvitia. Khar'kov: 47–49.

Saltykov A. N., Andreeva O. V., 2015: Prostranstvenno-vremennnaia zakonomernost' estestvennogo vozobnovlenia sosnovykh lesov NP „Smolenskoe Poozer'e". Materialy Mezhdunarodnoi nauchno-prakticheskoi konferencii. Domzhernitsy 26–29.08.2015: 119–123.

Saltykov A. N., Borisova V. L., Garmash A. V., 2015: Ekologicheskii i energeticheskii balans estestvennogo vozobnovlenia pridoneckikh borov. Nauchnye vedomosti BGU, vyp. 32, № 15 (212): 13–22.

Saltykov A. N., Tkach L. I., Motoshkov A. V., 2005: Postepennye rubki i osobennosti estestvennogo vozobnovlenia sosny. Vesnik KhNAU, Seria „Pochvovedenie, agrokhimia, zemledelie, lesnoe khozyaystvo", 1. Khar'kov: 169–173.

Saltykov A. N., Tkach L. I., Poznyakova S. I., 2006: Prostranstvennaia struktura estestvennykh sosniakov. Vesnik KhNAU. Seria „Pochvovedenie, agrokhimia, zemledelie, lesnoe khozyajytvo", 7. Khar'kov: 134–138.

Saltykov A. N., Vatlina T. M., 2015: Erarkhia, sopodchinennost' i faktornoe prostranstvo processa estestvennogo vozobnovlenia pridoneckikh borov. Problemy regional'noi ekologii, 6. Moskva: 36–42.

Sannikov S. N., Sannikova N. S., 1985: Ekologia estestvennogo vozobnovlenia sosny pod pologom lesa. Nauka, Moskva: 152 p.

Sinitsyn E. N., 2008: Estestvennoe vozobnovlenie sosniakov Usmanskogo i Khrenovskogo borov. VGPU. Voronezh: 307 p.

Shishkin A. S., 1969: Dinamika estestvennogo vozobnovlenia na lesosekakh razlichnykh sosnovykh rubok v suboryakh. Issledovania po lesovodstvu. Tr. KhSHI, 86 (123). Khar'kov 90–99.

Shishkin A. S., 1972: Vliyanie mer sodeystvia na estestvennoe vozobnovlenie sosny v svezhikh suboryakh. Issledovania po lesovodstvu i agrolesomelioracii. Tr. KhSHI, 169. Khar'kov: 64–74.

Vradiy N. I., 1961: Pristepnye bory Ukrainy i sposoby sozdania v nikh lesnykh kul'tur: dis… kand. s-kh. nauk. Khar'kov: 365 p.

Zlobin Y. A., 1976: Ocenka kachestva cenopopulyacii podrosta drevesnykh porod. Lesovedenie, 6: 72–79.

Received: 06 December 2016
Wpłynął do redakcji: 06 grudnia 2016
Поступила в редакцию: 06 декабря 2016