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DENDROCHRONOLOGICAL STUDY ON PALAEOWOODLAND DYNAMICS IN A WESTERN LITHUANIAN PEAT–BOG

Summary. Dendrochronological studies of Pinus sylvestris L. revealed growth phases of forests on a raised bog. An analysis of annual tree–ring widths of timber preserved in the raised bog in Uzpelkiu Tyrelis enabled interpretation of climate changes in the last 2000 years. Dendro chronological and radiocarbon dating of subfossil timber samples revealed evident separate afforestation phases occurred in the 7th - 8th c. and in the 10th - 11th c., corresponding to warm and dry climate conditions suitable for pine growth. Conditions unsuitable for pine growth occurred in the 9th c. and during the „little ice age" in the middle of the 2nd millenium AD.

BADANIA DENDROCHRONOLOGICZNE DYNAMIKI PALEOLASÓW NA WYSOKICH BAGNACH LITWY

Streszczenie. Na podstawie badań dendrochronologicznych odtworzono fazy rozwoju lasów Pinus sylwestris L. na wysokich bagnach. Analiza szerokości pierścieni rocznych przyrostów pni drzew zachowanych pod powierzchnią bagna w Uzpelkiu Tyrelis pozwoliła na interpretację zmian klimatu w okresie ostatnich 2000 lat. Datowania dendrochronologiczne i radiowęglowe próbek subfosylnych pni sosny ujawniły występowanie wyraźnie oddzielnych faz zalesiania. Początek pierwszej fazy zalesiania w okresie subatlantyckim przypada na II wiek BC. Fazy najobfitszego zalesiania miały miejsce w wiekach VII - VIII oraz X - XI, i odpowiadały warunkom ciepłego suchego klimatu sprzyjającego wzrostowi sosny. Fazy te występowały w wieku IX oraz w czasie „małej epoki lidowcowej"w środkowym okresie drugiego tysiąclecia AD.

1. Introduction

Tree rings of timber, preserved in the sites where the trees had been growing, are important source of knowledge about changing environmental conditions in the past. Differently from other palaeoclimatic proxy data, fluctuating annual growth of tree rings provide annual information about these changes. That is why dendrochronological investigation of subfossil timber besides to palinology and other geological and physical methods has to be used for palaeoclimatic and palaeoenvironmental research. Raised peat - bogs with their acid peat can be an ideal place for preservation of timber and protection of dendrochronological information for thousands of years. In this research dendrochronological method was used to reconstruct Pinus sylvestris L. woodland phases on a raised bog. Ring width analysis was used for interpretation of climatic fluctuations during the last 2000 years.

2. Material and methods

The investigated site, Uzpelkiu Tyrelis raised bog, is located in the north–west part of Lithuania, 47 km from the Baltic sea, in the region of Zemaitija Hills, 138 m above sea level. Geographical co–ordinates: latitude 56°05' N, longitude 21°50' E. The area of bog is 36.7 ha, mean thickness of peat is 3.4 m, the highest - 8.0 m. The beginning of bog formation took place in Boreal period (about 7000 years BC). Oligotro phical phase started in the end of Subboreal period (about 2500 years ago) (Bitvinskas T. et al., 1978). The earth surface is undulated as well as the bottom of bog and more or less layers of peat in this region.

The bog was drained some decades ago. Industrial excavation of peat facilitated the sampling of subfossil trees. In order to prepare the place for further peat excavation surface of bog was levelled by cutting out the first meter of peat. Only small outliers of surface peat layers were left undisturbed. About half of timber samples (Pinus sylvestris stumps and trunks) were collected from the levelled area (about 1 meter in depth from the actual surface of the bog). Other samples were collected from 2 ditches. The first was dug out in the area with the surface peat layers undisturbed and was 1 m in depth. The second one was dug out in the levelled area and represented peat layers from 1 to 2.5 meter in depth. The richest layers with greatest amount of timber were at depth of around 1.6 m.

About 300 samples of subfossil pine were collected in total (Bitvinskas T., 1978). In fig. 1 the distribution of samples with depth is shown. The largest amount of trunks was collected from 0.8 to 1.8 meter. Very few samples were found near the natural surface of the bog and the last deepest remnants, sound enough to fit for dating, were in the depth of 2.6 m.

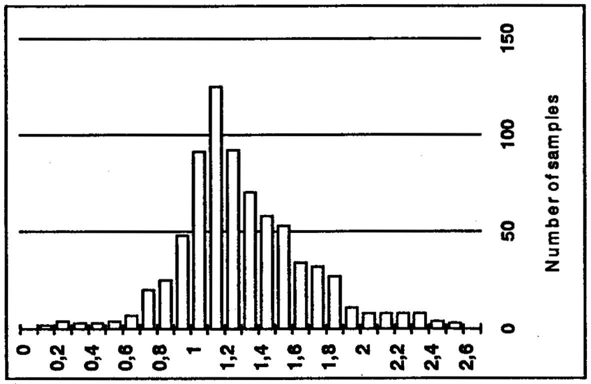

Fig. 1. Distribution of samples along the depth

Rys. 1. Rozkład pułapek względem głębokości

Twenty-eight samples were dated by ^{14}C method in the laboratory of Estonian Institute of Zoology and two – in the Institute of the History of material culture in St. Petersburg (Russia). Dates covered the period from now–days to 2090 years BP (before 1950 AD) (Bitvinskas T., 1978). Some of these dates were calibrated using Stuiver and Pearson calibration curve in the dendrochronological laboratory of Joensuu University (Finland), others – in the radiocarbonical laboratory of the Institute of the History of material culture in St. Petersburg (Russia). In fig. 2 radiocarbon dates of Uzpelkiu Tyrelis bog pines are shown (within the confidence intervals of 1 σ). Though there were some gaps, especially around 14th – 17th centuries, the sequence of ^{14}C dates gave a hope to construct a long – term dendrochronology for last 2000 years.

For establishing positions of tree life – spans in a time scale, cross – dating of tree ring patterns was used. Tree ring widths were measured in two radii using standard technique (Bitvinskas T., 1974). No standardisation of tree ring series was used, because age trend of Pinus sylvestris from boggy habitats is not expressed. Synchronisation of

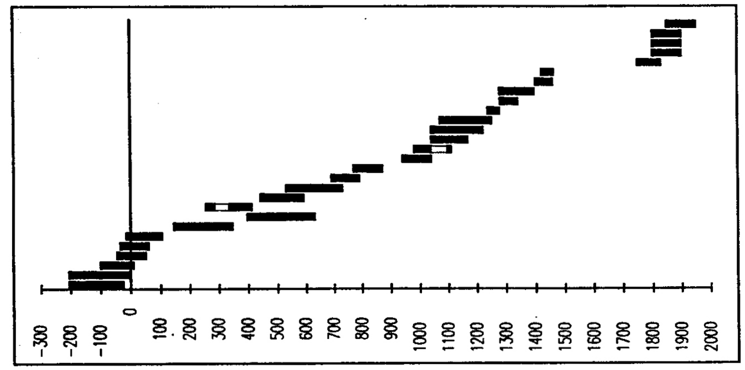

Fig. 2. ^{14}C dates of Uzprlkiu Tyrelis bog pines within 1σ confidence intervals

Rys. 2. Daty ^{14}C sosen z bagna w Uzpelkiu Tyrelis z przedziałami ufności 1σ

samples was visual and mathematical. Annual radial growth curves were compared on paper; percentage of sign agreement, correlation coefficient, and t values (Baillie and Pilcher, 1973) in different positions between tree ring sequences were calculated. Annual radial growth of synchronised samples was the basis to construct averaged chronologies.

3. Synchronisation of subfossil timber samples

During hundreds of years of being in peat usually only a small part of tree between stem and roots has remained preserved. But for dendrochronolo gical investigation this part is not very suitable. Because of the influence of root – growing tree rings are rather eccentric there. That diminishes the weight of fluctuations in annual growth due to exogenic factors common to all trees in a site. Missing of rings is quite often in poor habitats of raised bogs but in the lowest part of stem it is most frequent. Adding up peculiarities of tree–ring patterns characteristic for Pinus sylvestris from boggy sites due to differences in micro habitats the cross – dating based on the lower part of stem becomes more complicated. Individual peculiarities cause difficulties both in visual and mathematical synchronisation. In most positions of overlap t values between samples were less than 4. Only two groups of samples were found where t values among the trees were more than 5.

The problem of dissimilarities of individual tree – ring patterns is closely connected with the problem of pseudosynchronism in Pinus sylvestris, especially in the periods of time when some cycles in growth dynamics are expressive. There are cases when t value exceeds 4 in two or three positions of overlapping in the same pair of trees. Therefore conclusion about synchronism was made after thorough visual synchronisation and when not only a pair but some group of curves fitted with each other in the same position.

Dissimilarities between individual trees cause particular difficulties, when period of overlap is short. In our climatic conditions pines in bogs don't live very long. Only in rare cases the age of living trees exceeds 180 years. The mean age of excavated stumps was about 100 years, only 7 trees were older than 200. Especially short series were in the upper layers of bog. Because of these peculiarities only one third of samples was synchronised and included into further analysis.

The process of dendrochronological synchronisation revealed some separate phases in forest history. Some amounts of trees formed groups, where germination occurred in the close time. Such situations may be explained by rapid changes in hydrological conditions of the bog when dried surface becomes suitable for young pine tree regeneration (McNally A., Doyle G.J., 1984). Analysis of pollen (Bitvinskas T. et al., 1978) showed four peaks in the curve of pine pollen during the Subatlantic period. Decrease in quantity of pine pollen coincided with increase of spruce or birch pollen about 500 years, about 800, and about 1600 years ago. These fluctuations in forest succession on the bog and its surroundings are related to climatic changes.

4. Palaeoforest growth dynamics and its ecological background

In figure 3 relative positions of synchronised subfossil pine wood samples are presented in a time scale. The samples with ^{14}C dates included into groups were the basis to date the floating chronologies. In the most cases ^{14}C dates correspond each other but sometimes discrepancy exceeds 200 years. In fig. 4 an example of difference between radiocarbon dating and dendrochronological cross-dating of two samples from 10th – 12th centuries is presented. In such a way dendrochronological method corrected distribution of ^{14}C dates and as a result we see that abundance of trees was not equal during the last two millennia.

The oldest samples cover 2nd c. BC - 3rd c. AD. Especially the groups of cross-dated samples from around the 7th – 8th centuries AD, and from around the 9th – 11th centuries AD are well represented. Similarities among individual ring sequences are rather high there (t values are mostly above 4.5). The germination of trees from the 7th – 8th c. group was almost in the same time. Dating of these two groups coincides with the big peak of pine pollen in the pollen diagram from the bog (Bitvinskas T. et al., 1978). Very few samples with narrow rings represent 5th – 6th centuries AD.

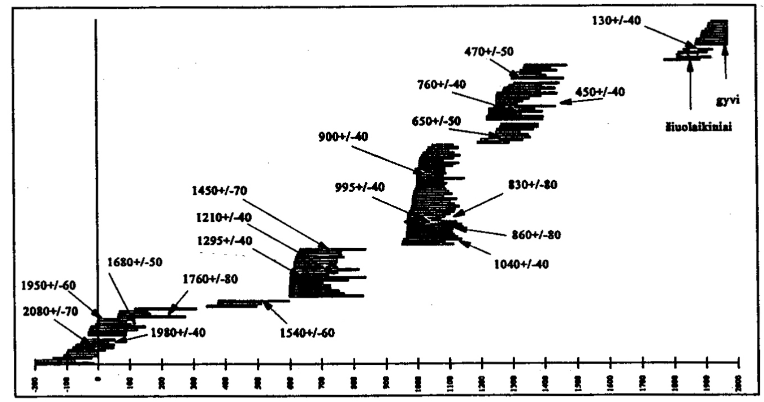

Fig. 3. Cross-dated Uzpelkiu Tyrelis bog pine series. Floating groups are dated by radiocarbon. ^{14}C – dated rings (BP) are marked in black

Rys. 3. Diagram korelacyjny pni sosen z bagna Uzpelkiu Tyrelis. Pływające chronologie datowano metodą radiowęglową. Pierścienie datowane metodą ^{14}C oznaczono na czarno; wiek w latach BP

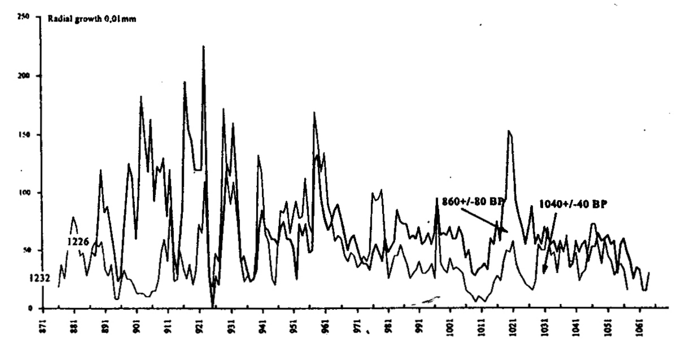

Fig. 4. Difference between radiocarbon dates of two samples from the same age

Rys. 4. Różnica między datami radiowęglowymi dwóch równoległych próbek

In the second millennium AD the group of samples coming from the 13th – 15th c., and the group of modern samples (19th c.) connected with the living – tree chronology was found. Samples from the 13th – 15 c. have rather individual tree – ring patterns and form two groups still not crossdated. Individualities of growth dynamics and difficulties of radiocarbon dating from this time period prevent us meanwhile to make firm conclusion if these groups represent different generations or they grew at the same time but differences in growth patterns represent differentiation of micro habitats.

In the Figure 5 the annual radial growth dynamics of reconstructed woodland phases are presented. In the spell of 2000 years there were rather expressive changes in the annual growth of bog pine. Growth variability of trees depends on the environmental conditions. Research on modern, living trees from this raised peat – bog revealed positive correlation between annual radial growth fluctuations and February - September temperatures, and negative correlation with annual precipitation (Piksryte R., 1994). It means that during climatic optima – warm and dry periods – pine in this peat bog had wider tree rings than during cold and wet periods.

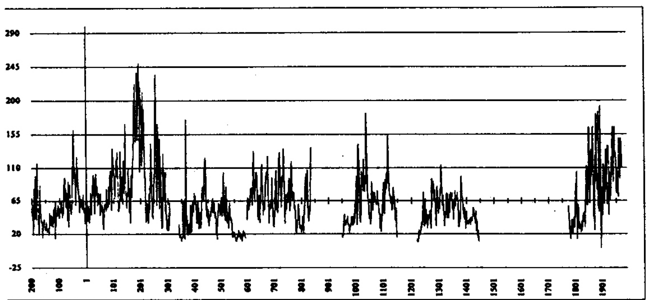

Fig. 5. Annulal radial growth of Pinus sylvestris L. in Uzpelkiu Tyrelis raised bog within two millenia

Rys. 5. Roczne przyrosty promieniowe Pinus sylvestris L. z wysokiego bagna w Uzpelkiu Tyrelis w okresie 2 tysiącleci

Analysis of abundance of tree remnants from different time periods (fig. 3) shows that the most abundant group comes from 10th – 11th century – time in climatology known as „little climatic optimum" (Barash S.V., 1989). Chronology of this group has two intervals of better growth when tree – ring width was above long – term average during 30 – 50 years. Evidence about warm and dry climate from around 11th century comes from different sources. Reconstruction of summer temperatures from continuous tree – ring records from northern Sweden shows warm period from the beginning of 10th until the end of 11th century (Briffa K.R. et al., 1992) (fig. 7). Glaciological investigations reveal retreat of Alpine glacier in the second half of 10th c. (Zumbuhl, Holzhauser, 1988) (see fig. 6). Similar information about suitable conditions for grape culture in England, Vikings settlements in Greenland, etc. contains in chronicles and annals but these sources report that there were a lot of cold winters and wet summers too (Barash S.V., 1989). Tree – ring records show periods even during „little climatic optimum" with less favourable

growth conditions which are not registered in not so sensitive glaciological or palinological investigations.

The second most abundant group of samples covers 7th – 8th centuries. There is not very much information about climate of this time and evaluations sometimes contradict each other. For instance, V.I.Turmanina (1979) referring to established by G.K.Tushinskij „Archize break" of ice formation in the Caucasus in 8th – 12th centuries and other proxy data evaluates period of 8th – 12th c. as dry but 4th – 7th c. as wet. S.I.Barash (1989) referring to S.I.Kostin names period of 5th – 8th centuries as „the second kserothermic period" during Holocene and basing on analysis of chronicles establishes increase of wetness during 8th – 10th c. Dynamics of pine forest formation on Uzpelkiu Tyrelis raised bog and annual radial growth of trees support estimation of climate around 7th c. as dry and warm, because so short time of formation of this generation could be due to rapid drop of water table or after fire. Annual radial growth mostly above long - term average shows optimal conditions during more then 100 years. Quasi solar cyclicity (it is with periods around 11 and 22 years) is characteristic for the growth fluctuations of this time. Barash (1989) referring to Reis mentions 7th c. as famous with climate extrema and such anomalous phenomena like magnetic storms and northern lights due to changes in Earth – Solar connections and Solar activity.

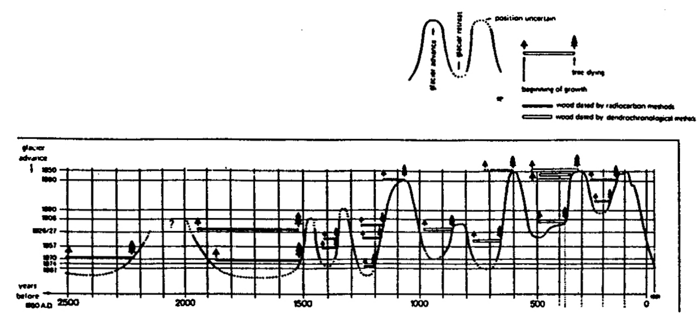

Fig. 6. The fluctuations of Glosser Aletschgletschers in Switzerland reconstructed using dendrochrnological methods (from Zumbuhl and Holzhauser, 1988)

Rys. 6. Fluktuacje lodowca Glosser Aletschgletschers w Szwajcarii zrekonstruowane na podstawie metody dendrochrnologicznej (Zumbuhl and Holzhauser, 1988)

These two most abundant groups showing favourable conditions for pine stand in the bog don't crossdate with each other. Gap between these phases coincides with glacier advance in the Alps in 9th c. (see fig. 6) and cold period in July – August temperature fluctuations in Northern Fennoscandia around 800 AD (fig. 7). Conclusion can be maid, that unfavourable conditions in 9th c. separated two optimal periods around 7th c. and

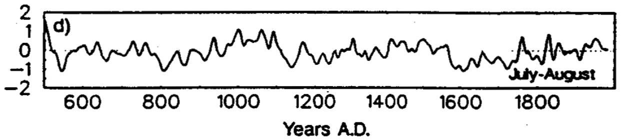

Fig. 7. Reconstruction of July–August mean temperatures in northern Fennoscan dia using continuous tree–rung records (from Briffa et al., 1992

Rys. 7. Rekonstrukcja średnich temperatur lipca–sierpnia w północnej Fennoscandii na podstawie sekwencji pierścieni rocznych przyrostów drzew (Briffa et al., 1922

around 11th c. May be less sensitive methods of past climate evaluations leads to mixture of these two optima and fixing the beginning of „little climatic optimum" in the 8th c. AD (see Turmanina, 1979)

The oldest excavated trees – the first ones after the bog turned to oli gotrophical in the end of Subboreal period – began to grow in the 2nd century BC. The first trees were not long – lived and there was not mass – germination. Annual radial growth began to exceed long – term average in the middle of the 1st c. BC. The highest annual growth was in the 2nd – 3rd centuries AD. Barash (1989) referring to S.I.Kostin and J.L.Rauner evaluates the first two centuries as the warmest in our times. Referring to chronicles he evaluates beginning of the first millennium AD as warm and wet with rapid change to dryness in the 70 – s of the 1st c. Wide tree – rings in Uzpelkiu Tyrelis bog show optimal combination of warmth and dryness up to the end of the 3rd c. AD.

Narrow tree – rings are characteristic to the trees that grew during the 4th – 6th centuries AD. Evaluations of climatic conditions of this period have some controversy. Barash (1989) mentions wetness in the 4th c. with increasing dryness from the end of the 4th c. until the 8th c. Turmanina (1979) evaluates all the period of the 4th – 8th centuries as wet. Trees from Uzpelkiu Tyrelis bog show unsuitable growth conditions during the 4th – 6th centuries AD.

Less than long – term average growth is characteristic for trees from the 13rd – 15th centuries. After this phase some centuries there were no pine forest in this bog. Evidently conditions of „the little ice age" were unfavourable for pine forest.

Pine forest regeneration took place in the end of the 18th c. and in the middle of the 19th c. tree – ring width exceeded average. The annual radial growth of living trees from this bog almost all the 20th century has been above 2000 year's average. It shows that warming climate has positive influence on pine growing in raised bogs. But there were periods in the past two millennia with similar or even better growth conditions.

5. Conclusions

Dendrochronological and radiocarbon dating of subfossil timber samples revealed not even distribution of pine trees during 2000 years of bog history. Separate afforestation phases become evident.

The beginning of the first afforestation phase in Subatlantic period took place in the 2nd c. BC. The most abundant afforestation phases occurred in the 7th – 8th centuries and in the 10th – 11th centuries. Gap between these two phases shows unsuitable conditions for pine in the bog in 9th c. between two optimal periods. Unsuitable conditions for pine growth were also during „little ice age" in the middle of the II millennium AD (14th – 18th c.).

Analysis of annual radial growth of reconstructed forest phases gives information about changes of former climate. Periods with narrow tree–rings or gaps between afforestation phases in some extent correspond to glacier advance in Alps (Zumbuhl, Holzhauser) and periods characterized as cold or wet in other sources (6th c. AD (Barash, 1989, Turmanina, 1979), 9th c. AD (Briffa et al., 1992, Zumbuhl, Holzhauser, 1988), second half of 12th c. (Briffa et al., 1992), 14th – 17th c. (Barash, 1989 etc.)); Periods with wider tree–rings confirm warm and dry conditions in the beginning of 1st millennium AD, 7th – 8th c., 11th c., 20th c. AD.

Correspondence of Pinus sylvestris growth conditions in Uzpelkiu Tyrelis raised bog to evaluation of past climate from other sources indicates that woodland dynamics depended not only on local conditions but also reflected the larger scale climatic fluctuations.

Dendrochronological method investigating the former environment has good resolution in time scale and should be used in larger extent.

For covering gaps between the floating Uzpelkiu Tyrelis chronologies and dating life spans of tree groups with accuracy of one year dendrochrono logical material from other similar objects – raised bogs is necessary.

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Streszczenie

Na podstawie badań dendrochronologicznych odtworzono fazy rozwoju lasów Pinus sylwestris L. na wysokich bagnach. Analiza szerokości pierścieni rocznych przyrostów pni drzew zachowanych pod powierzchnią bagna w Uzpelkiu Tyrelis pozwoliła na interpretację zmian klimatu w okresie ostatnich 2000 lat. Datowania dendrochronologiczne i radiowęglowe próbek subfosylnych pni sosny ujawniły nierównomierny rozkład drzew sosny w okresie 2000 lat historii bagna. W wyraźny sposób stwierdzono występowanie oddzielnych faz zalesiania. Początek pierwszej fazy zalesiania w okresie subatlantyckim przypada na II wiek BC. Fazy najobfitszego zalesiania miały miejsce w wiekach VII – VIII oraz X – XI. Przerwa między tymi fazami wskazuje na występowanie warunków nie

sprzyjających sośnie w wieku IX, między dwoma okresami optymalnymi. Warunki niesprzyjające wzrostowi sosny występowały również w czasie „małej epoki lodowcowej" w środku II tysiąclecia AD (XVI–XVIII w.) Analiza rocznych wzrostów promieniowych w zrekonstruowanych fazach leśnych dostarcza informacji o zmianach klimatu w przeszłości. Okresy z wąskimi pierścieniami rocznymi lub przerwy między fazami zalesiania odpowiadają w pewnym stopniu transgresjom (?) lodowców alpejskich oraz okresom chrakteryzowanym jako zimne lub wilgotne w innych źródłach. Okresy z szerszymi pierścieniami rocznymi potwierdzają występowanie ciepłych i suchych warunków początku I tysiąclecia AD, VII–VIII w., IX w., XX w., AD.

Zgodność warunków wzrostu Pinus sylvestris na wysokim bagnie w Uzpelkiu Tyrelis z oceanami przeszłego klimatu w przeszłych środowiskach wskazuje, że dynamika terenów leśnych zależy nie tylko od warunków lokalnych ale odzwierciedla również fluktuacje klimatu w większej skali.

Metoda dendrochronologiczna badania środowiska w przeszłości ma dobrą zdolność rozdzielczą w skali czasu i powinna być lepiej wykorzystywana.