The coefficients s and A are obtained experimentally from the single analysis of vendace population of the river Hatanga (Lukjanchikov, 1967). These coefficients as well as coefficient k are constant in the calculations of the model even though there are no restrictions to consider their dependence on the current conditions of the complex dendrochronological index.

In correspondence with the representation of dynamics of fish number and fish mean weight, withdrawal was calculated for each year:

$$Y(t) = (1 - k) \sum_{j=1}^{n} x_j y_j \quad .$$

Representation of a small number of coefficients of the model obtained experimentally makes it possible to compute numerical calculations of vendace fishing using known dendrochronological series. Corresponding calculations made according to the conventional age model demonstrated a good correlation between calculated and real curves of catch (*Figure 6.23*) with a high correlation coefficient (+0.875).

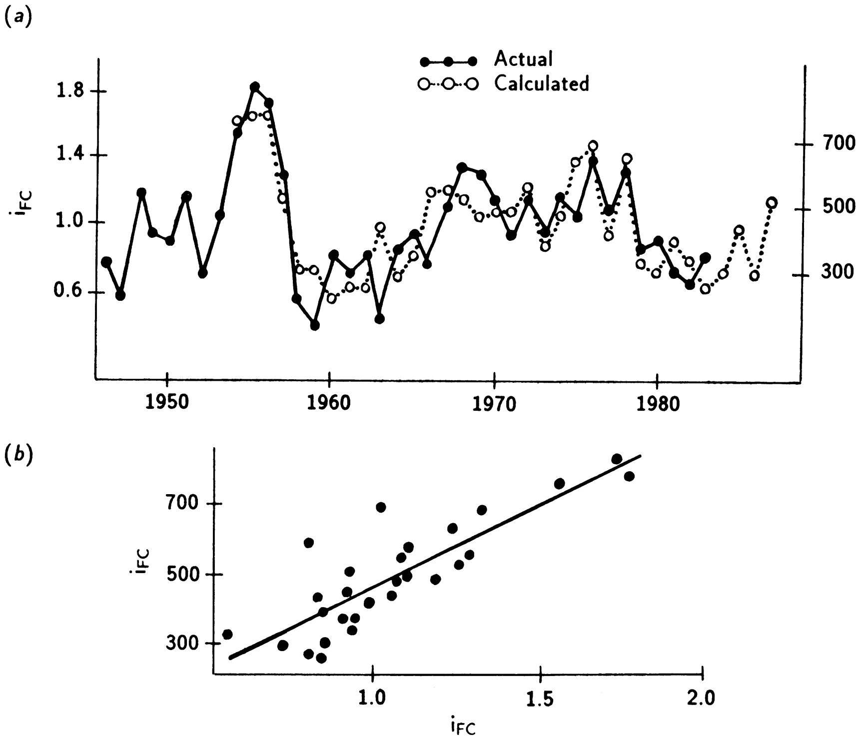

Figure 6.23. Comparison of dynamics of actual and calculated values for vendace fishing (*a*) and correlation between them (*b*).

Apparently, this approach to ecological forecasting may be used not only for ecosystems with one factor of growth limitation. Actually, in each year, the growth rate may be influenced by several environmental factors; therefore the correlations between the growth parameters and environmental factors are multiple. The left part of the time-sequence data can then be used to create a multiple regression model to calculate the characteristics of one process using independent characteristics from the other. The right part of the sequence (series) can be used to verify the regression model and forecast.

6.5.4. Prediction in forest practice

Predictions of ecoclimatic fluctuations of short duration have already found applications in the practice of forestry. For example, in the Lithuanian SSR, fertilizers in the forest are applied two years before the predicted maximum increment for the same forest under ideal conditions, using the 11-year cyclicity in dendrochronologies. Also, timing of forest thinning is rescheduled according to the maximum increment predicted. The thinning effect is higher when thinning is applied two to three years before the predicted maximum increment. Forest reclamation is also applied one to two years after the maximum forest increment on the same soils predicted by dendrochronologies. Using these measures has made it possible to obtain an additional 15–30% wood increment.

The ability to predict ecoclimatic fluctuations of long duration for entire regions opened up new spheres for the application of dendrochronology in planning forest use as well as in the practice of regional management.

For example, as was stressed in the resolution drawn up at the Workshop on Forest Decline and Reproduction: Regional and Global Consequences (Krakow, Poland, 1987), the long-term ecological background changes influence to a considerable extent the sustainability and productivity of forest ecosystems, sometimes strengthening and sometimes weakening them. The long-term changes of forest-system productivity as illustrated in *Figure 6.17* can lead to further decline and changes in the amount of estimated forest use, particularly when short rotation is being applied. There are scenarios calculated for allowable wood cutting until the year 2135 for the Lithuanian region using long-term dendrochronological cycles (Kairiukstis *et al.*, 1987a). Scenarios revealed a decrease in available wood by the middle of 21st century in the Baltic region due to unfavorable climatic changes and long-term forest decline.

6.6. Prognosis of Tree Growth by Cycles of Solar Activity
T. Bitvinskas

In the Dendro-climato-chronological Laboratory of the Institute of Botany (Lithuanian Academy of Sciences) some pointer or registration years were used to which radial tree growth could be *attached* to forecast environmental conditions of forest growth. Solar activity expressed by the number of sunspots (according to Wolf) for hydrological years was chosen as the basis for selecting pointer years. It was shown that in certain regions of the USSR there is a clear correlation between the amplitude of the 22-year cycles and the radial tree growth during the same period (Bitvinskas, 1967, 1971). In different phases of the solar activity at maxima marked *a* and *b* and minima marked *c* and *d* as well as in time periods of increasing and decreasing solar activity marked *ac* and *cb* and *bd* and *da* (*Figure 6.24*), forest growth in varying regions and under various growth conditions is very different.

Research was based on the assumption that at certain phases of solar activity, we can expect – with certain probability – extreme radial tree growth (maximum or minimum) for given periods of time. The method conceived involved all the processes that have affected tree growth during certain phases of the solar activity.

Hydrological years (September–December of the previous year through January–August of the present year) of the highest and lowest solar activity are considered pointer years for *attachment* of dendrochronological data. The central year of the three years with extreme values of the Wolf sunspot number are considered pointer years. We attached yearly data of tree-rings and their indices to the pointer years of the solar activity and studied the growth trend for given regions, sites, and species. Confirmed data can date the Wolf sunspot number as far back as 1749, which at present form twenty-one 11-year and eleven 22-year cycles. Solar activity series in the pointer years systems were checked according to Shove's system (see Vitinskiy, 1963; Vitels, 1977). Ecological forecasting is based upon the definite prognoses of 11-year and 22-year cycles of the solar activity. It is known that the prognosis of the solar activity is guided by mathematical modeling of regularities of variability of the Wolf sunspot number (Vitinskiy, 1963, 1983; Vitels, 1977). We tried to use the method of overlapping epochs while making up generalized series of the solar activity for the hydrological year to reveal the distinctive features in time for the 22-year cycles as well as the 44-year and 88-year cycles. *Table 6.3* shows the pointer years of the solar activity according to the first and second maxima (*a*, *b*) and the first and second minima (*c*, *d*) of the solar activity including prognosis collated statistically.

The average data on solar activity allow one to calculate the average variability and to use it as the standard. We can thus forecast and reconstruct (*Figure 6.24*).

With this pointer year system, it is easy to make tables of the relationships between dendroclimatological data and the pointer years of past solar activity. If there are long enough series of natural phenomena (e.g., tree-ring indices, air temperature, precipitation, complex climatic indices, earthquakes), the method can be used to process this information and reveal whether there are some regularities connected with solar activity. The width of tree-rings or calculated yearly indices can be easily attached to the maximum and minimum of the 22-year cycles of the solar activity from 1745 to the present. This numerical and graphical method enables one to link the different increments of a tree's different phases to solar activity. For example, the distribution of dendrochronological indices of *Pinus sylvestris* in western Lithuania, according to the years in relation to pointer years of the first maximum solar activity, is shown in *Table 6.4*.

Table 6.3. Pointer years of the solar activity.

Cycle no.	*Phases of the solar activity* — *a* First maximum	*c* First minimum	*b* Second maximum	*d* Second minimum
0			1751	1755
1	1761	1765		
2			1770	1775
3	1779	1784		
4			1788	1798
5	1804	1811		
6			1817	1823
7	1829	1834		
8			1837	1843
9	1849	1856		
10			1860	1867
11	1871	1876		
12			1884	1889
13	1894	1900		
14			1907	1913
15	1918	1923		
16			1928	1933
17	1937	1944		
18			1948	1954
19	1958	1964		
20			1969	1976
21	1980	(1987)		
22			(1991)	(1997)

Table 6.4. Distribution of yearly indices of pine (*Pinus sylvestris*) in Neriga, western Lithuania (soil site: *Pinetum Oxalidosa-myrtilosum*); to the years of the first maximum of solar activity.

Group of cycles	*Cycles*	*Value of yearly indices*											
1	1	108	103	84	128	108	127	103	97	124	107	89	80
2	3	118	98	104	117	138	45	36	62	76	85	116	119
1	5	88	111	130	141	34.5	29	49	67	90	70	67	77
2	7	127	90	76	106	120	85	71	116	113	89	90	77
1	9	49	116	117	96	81	100	110	64	37	62	122	160
2	11	155	104	74	53	77	112	133	108	90	116	128	118
1	13	102	111	98	88	126	181	102	85	115	71	34	48
2	15	28	82	121	160	132	114	125	91	91	90	84	109
1	17	97	83	78	93	104	137	123	132	64	142	117	94
2	19	102	80	92	86	107	94	140	76	59	54	83	114
I gr.	M	89	105	101	109	91	115	97	89	86	90	86	92
II gr.	M	106	91	93	104	115	90	101	91	86	87	100	107
M	Aver.	97	98	97	107	103	102	99	90	86	89	93	100
		–5	–4	–3	–2	–1	0	+1	+2	+3	+4	+5	+6

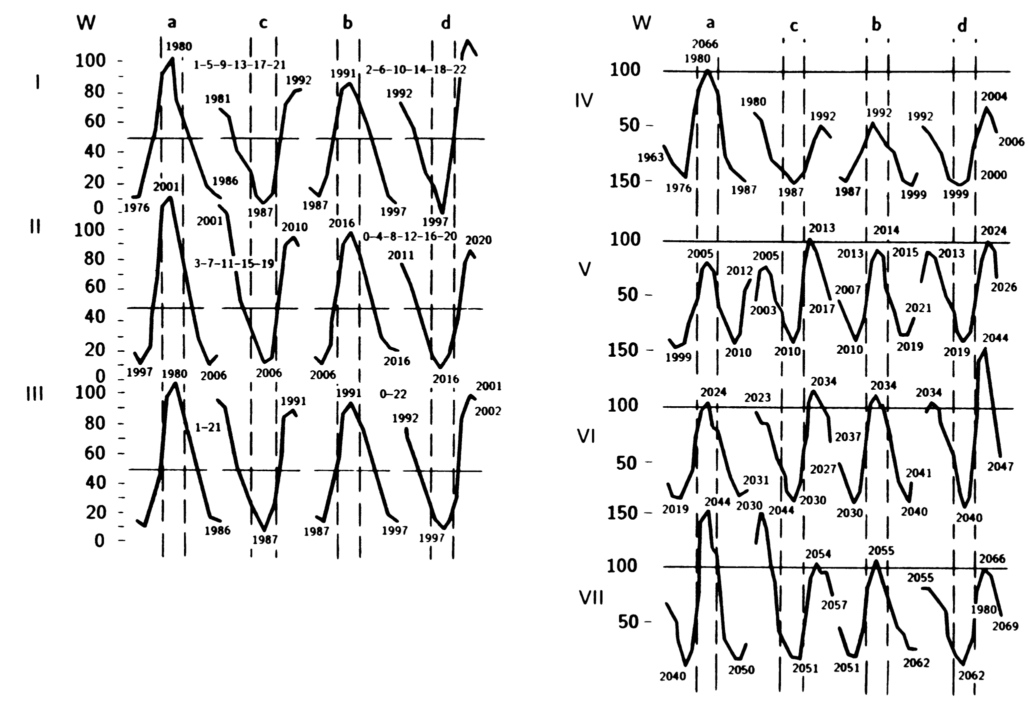

Figure 6.24. Conditional prognoses of 22-year (I, II), 44-year (III), and 88-year (IV, V, VI, VII) cycles of solar activity, calculated according to adequate variability of values of the Wolf sunspot number: W (Wolf sunspot number averaged for adequate cycles); *a,b,c,d* (pointer years of solar activity); 1-5-9,... (cycles numbers, see *Table 6.9*); 1976, 1980,... (calendar years, 1–21 for whole single and 0–22 for whole even cycles).

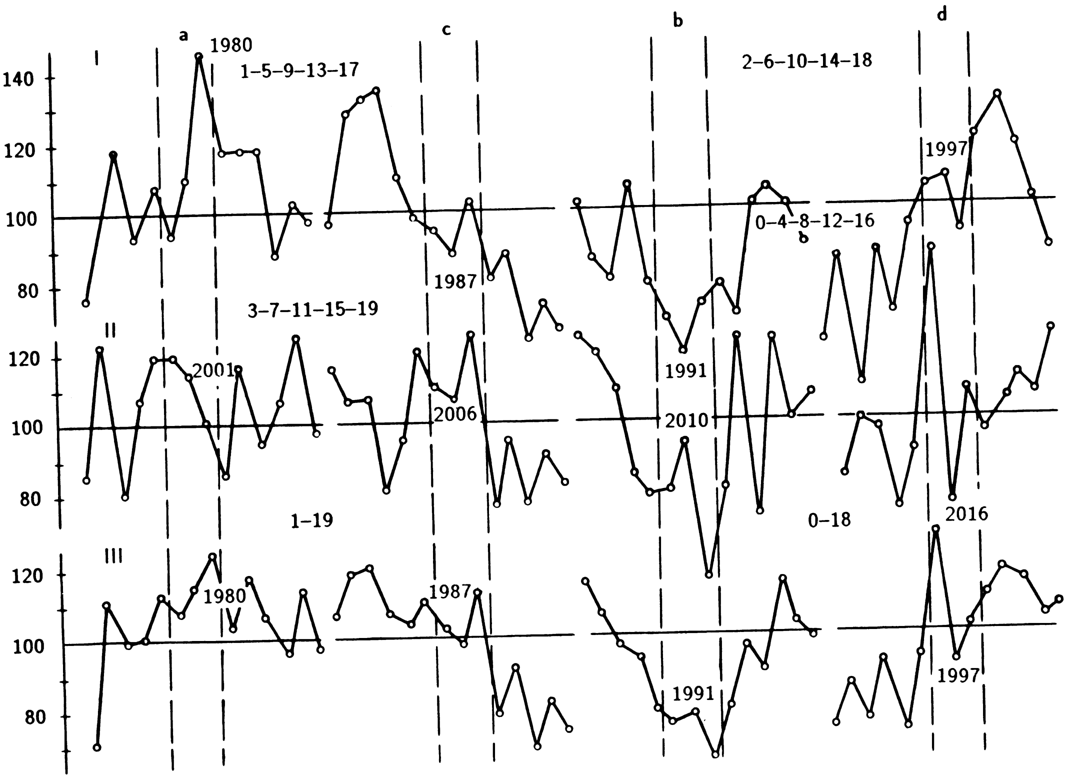

Figure 6.25. Current and anticipated tree-growth indices for *Larix sibirica* in the polar Ural Mountains attached to pointer years forecast from solar activity. (From Shiyatov, 1986.)

Regularities of growth thus revealed from the past are transferred to the future and attached to anticipated pointer years (a,b,c,d) of solar activity. Thus, for instance, current and anticipated tree-growth indices calculated by the method above are presented in *Figure 6.25* for polar Ural Mountains, according to dendrochronologies of *Larix sibirica* published by Shiyatov (1986). By comparing these results with the prognosis of forest growth in the west Siberian forest tundra derived by approximation and extrapolation by sinusoids (*Figure 6.8*), great similarity can be found.

Summing up we can state that the pointer year system of the solar activity is one method that allows one to foresee the future trend of tree growth according to the regularities of the growth in the past.

6.7. Possible Future Environmental Change

P.D. Jones

6.7.1. What major environmental changes are expected over the next century?

The major change in the environment over the next 50 to 100 years is expected to result from changes in the climate due to increasing concentrations of carbon dioxide and other gases in the atmosphere. Since about 1750, and particularly since the middle of the 19th century, CO_2 concentrations have increased as a result of the activities of man. CO_2 concentrations in 1985 were 345 ppmv, a value that is almost 25% more than the level that is now thought to have existed in the 1850s (Neftel *et al.*, 1985; Raynaud and Barnola, 1985). Apart from carbon dioxide, concentrations of other radiatively active trace gases, such as CH_4, N_20, 0_3, and CFCs (which act like CO_2), have been increasing rapidly over the last 25 years. Based on projected future energy use scenarios, it is to be assumed that these gases will continue to increase and the concentration of CO_2 and other trace gases (converted to equivalent CO_2) will double the 1850 preindustrial level by as early as 2030 (Bolin *et al.*, 1986).

The potential climatic effects of this increase in CO_2 and other trace gases in the atmosphere, as estimated by numerical models of the global climate system, would constitute a major alteration to the present climate regime and have far-reaching economic and social implications. The latest model results indicate that the global mean temperature would increase by between 1.5 and 4.5°C as a result of the CO_2 and other trace gas increases (MacCracken and Luther, 1985; Bolin *et al.*, 1986). The rise will not be rapid but will occur gradually, albeit with increasing speed, over many years. Because of the nature of the climate system and the inherent lag of the system to forcing, the full effects will not be evident until many years after equivalent CO_2 levels have doubled. The latest projected rise over the next 25 years (i.e., to 2010) is for an increase of between 0.3 and 0.6°C. Such a rise is of the same magnitude as the rise in global temperatures that has occurred during the last 100 years.

The increase in global mean temperature will not be uniform over the Earth. Most areas will warm, but some may even cool. General Circulation

Models (GCMs) suggest that the greatest warming will occur in polar latitudes and be amplified during the winter half of the year. Such projections are based on an instantaneous equilibrium response to increased CO_2 levels. In the real world CO_2 concentration will increase gradually and the transient response may be different from the equilibrium response with its fixed CO_2 level.

Overall temperature rise is not the only response of the climate system to the change in the thermal regime of the Earth caused by the adjustment to the radiation budget of the planet. There will be associated alterations in the present precipitation and pressure patterns affecting almost all aspects of the climate system. However, just as the spatial pattern of the temperature response can only be estimated, the spatial nature of the changes in these other parameters can also only be projected – with varying degrees of uncertainty.

Two types of analysis have been used to try to assess possible future changes in the climate. Both have their limitations, and both must be considered as guides or scenarios as to what might happen. They are not forecasts but best possible projections that fit the facts as we currently know them. Scenarios can be developed using either past instrumental or proxy data from previous warm periods or GCM model projections of what the climate might be in a higher CO_2 world. Instrumentally or proxy-based scenarios have some advantages because they occurred in the past. They are based on the assumption that any pattern of warming will be similar whatever the cause. Warm periods from the past can therefore be used as analogs to the future. The arguments against such scenarios are that the projected increase in global mean temperatures, likely to occur in the future, is much greater than any previous warm period and the response of the climate system may not be linear. The argument against GCM-based scenarios is that GCMs do not model present-day climate well; therefore, confidence cannot be placed in their projections.

The use of the scenario approach has been widespread. Potential implications for agriculture have been discussed by Warrick *et al.* (1986a, 1986b) for water resources by Callaway and Currie (1985), for forestry by Shugart *et al.* (1986) and by Solomon and West (1985), and for climate by Webb and Wigley (1985) and by Wigley *et al.* (1986).

For forestry, Solomon and West (1985) identified the following five important areas:

(1) The life spans of trees are long; unlike crops, experimentation in the field throughout the life of the tree is not possible. We therefore require complete understanding of tree dynamics.
(2) Although management is important, forests are dominated by the stability of the climate and any climatic change. It is therefore vital to understand this if forest management techniques might ameliorate the effects of climatic change.
(3) The direct effects of increasing atmospheric CO_2 concentrations range from growth enhancements to growth retardations.
(4) Combined with the indirect effects of climatic warming, air pollution, and other environmental factors, forests can respond by enhancing growth or by forest dieback.