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EFFECTS OF GLOBAL ATMOSPHERIC PERTURBATIONS ON FOREST ECOSYSTEMS: PREDICTIONS OF SEASONAL AND CUMULATIVE EFFECTS; R.W. Tinus, USDA-Forest Service, Rocky Mountain Station, Flagstaff, Arizona, and D.J. Roddy, U.S. Geological Survey, Flagstaff, Arizona

The physical effects of certain large events, such as giant impacts, explosive volcanism, or combined nuclear explosions, have the potential of inducing global catastrophes in our terrestrial environment [1,2,3,4,5,6,7]. Such highly energetic events can inject substantial quantities of material into the atmosphere [8,9]. In turn, this changes the amount of sunlight reaching the Earth's surface and modifies atmospheric temperatures to produce a wide range of global effects. One consequence is the introduction of serious stresses in both plants and animals throughout the Earth's biosphere [5,6,7]. For example, recent studies predict that forest lands, crop lands, and range lands would suffer specific physical and biological degradations if major physical and chemical disruptions occurred in our atmosphere [6,7]. Forests, which cover over 4 X 10^9 hectares (4 X 10^7 km^2) of our planet, or about 3 times the area now cultivated for crops, are critical to many processes in the biosphere. Forests contribute heavily to the production of atmospheric oxygen, supply the major volume of biomass, and provide a significant percentage of plant and animal habitats.

Recognition of the serious consequences of major disruptions of global forest ecosystems has prompted increased research in these areas [5,6]. For example, studies in the growth facility of the USDA Forestry Sciences Laboratory at Flagstaff, Arizona, permit predictions of some of the effects of sunlight and temperature perturbations on several major tree species and their forest relations. Drawing on these and other data, and assuming that a large event, such as a giant impact, can cause global atmospheric pollution with sunlight reduced by ~50% and atmospheric temperatures lowered by ~15 °C, we predict a number of negative consequences for forest ecosystems. For simplicity, we further assume that the atmospheric perturbations occurred in temperate zones during only two seasons, winter and spring; the atmospheric effects are considered to last on the order of 3 to 9 months.

In general, forests are composed of perennial plants whose lifetimes are measured in tens of years; the plants are exposed continuously to their local environments throughout all seasons. However, the vulnerability of forest trees in temperate zones varies greatly and in complex ways when stresses are imposed during different seasons. For example, global pollution would cause the least damage in the winter when the trees are dormant. Cold hardiness is usually more than adequate for any temperatures that the trees are likely to encounter, except at the northern limits of the temperature range of a species. In winter, when temperatures are high enough, evergreens normally use sunlight for photosynthesis, but sunlight is not necessary for their survival if winter persists for less than a year; deciduous trees are unaffected even by total darkness in winter. With reduced atmospheric gas exchange, most trees would have minimal susceptibility to noncorrosive air pollution. During a period of 3 to 9 months, the trees would remain dormant as long as cold and darkness persisted. However, when budbreak finally did occur, low light intensity would be detrimental, because it would impede accumulation of food reserves during the shortened growing season. One serious consequence of atmospheric pollution in the winter would be that it would leave the trees highly starved and poorly able survive the following fall and winter.

The most severe consequences of global pollution would occur in spring when new growth is underway and food reserves and cold hardiness are at a minimum. New growth would be severely damaged or killed by frost, resulting in the loss of at least a year's growth. The damaged tissue would be invaded by pathogens that would cause additional dieback. Deciduous forest trees would be hurt more than evergreens because the entire year's normal growth of foliage would be lost. Species demanding high light would suffer more damage than those tolerant of shade. Because of low food reserves, the next flush of growth would be meager, although new foliage would be better adapted to low light intensities than previous foliage. Air pollution would seriously shorten the useful life of foliage; such pollution, combined with low light intensity, would prevent recovery of food reserves. The longer that such adverse conditions persisted into summer and fall, the greater the degree of damage. Most trees would not be able to cold harden in a timely manner and would die during early fall freezes. Severe atmospheric pollution caused by events occurring in either summer or fall would have effects intermediate between those described above for winter and spring.

The effects of air pollutants are moderately well known for many species, but not at the acute doses envisioned here. The attendant but critical effects of reduced light intensity on rates of photosynthesis, both in tree growth chambers and in field situations, are also well documented for some species. The sparsest data are on temperature perturbation effects. Growth as a function of day and night temperature is known for only a dozen or so commercially important species. General information on maximum cold hardiness in winter is known for perhaps 300 species and horticultural cultivars. However, rates and degree of onset and loss of cold hardiness during the annual growth cycle are poorly known. Before any comprehensive picture emerges for global catastrophes in forest ecosystems, additional research is needed on subjects such as atmospheric physical and chemical overloading, sustained increases and decreases in sunlight and temperature, different seasonal conditions and stress durations, latitude variations, atmospheric global circulation modeling, and interaction among biologic species. Where possible, such research should include data on stress results from growth laboratory and field studies.

REFERENCES

[1] Alvarez, L.W., Alvarez, W., Asaro, F., and Michel, I.V. (1980) Sci. 208, 1095.
[2] Alvarez, L.W. (1980) EOS, 67, 649.
[3] Silver, L.T., and Schultz, P.H., eds. (1982) GSA Spec. Paper, 190, 461.
[4] Shoemaker, E.M. (1983) Ann. Rev. Planet. Sci., 11, 461.
[5] Elliot, D.K., ed. (1986) Dynamics of Extinction, John Wiley and Sons, 294.
[6] Grover, H.D. (1987) DNA Ecological Effects Workshop: Defense Nuclear Agency, Washington, D.C.
[7] Auton, D.L., Chairman (1988) Global Effects Program Technical Meeting: Defense Nuclear Agency, Washington, D.C.
[8] Ahrens, T.J., and O'Keefe, J.D. (1988) JGR, in press.
[9] Roddy, D.J., Schuster, S.H., Rosenblatt, M., Grant, L.B., Hassig, P.J. and Kreyenhagen, K.N. (1987) Int. J. Impact Engng., 5, 525.