thrown into sharp relief. Nonetheless, the effect of the NPDES program is visible in the dramatic recovery of Lake Erie water quality and fisheries, the improvement of previously dead rivers in the industrial northeast, and the drive to develop the technology that allows polluters to meet or exceed required effluent reductions.

SEE ALSO: Nutrients (as contaminants of water); Pollution, Sewage and Sewer Systems; Total Maximum Daily Loads (TMDLs); Water; Water Law; Wetlands; Wetlands Mitigation.

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Clear-Cutting

CLEAR-CUTTING IS A logging method is which whole stands of trees are non-selectively harvested over a relatively large area. The goals of the technique are to maximize economic efficiency in harvesting or create conditions to re-establish stands of trees species that require sunlight for growth, or both. As an economic efficiency measure, it allows loggers to access and remove all of the valuable older trees without having to work around protected trees and younger trees of lesser value. As an ecological management tool, it allows large contiguous areas to be opened to sunlight and regrowth.

Clear-cutting has been controversial since World War II, when it became the dominant logging method in U.S. national forests; some foresters see it as a beneficial and legitimate logging method, while some environmentalists find clear-cutting to be environmentally detrimental. Silviculturists propose clear-cutting as a necessary practice for even-aged forest regeneration: to remove trees that have been impacted by disease and/or insects; to convert land to a new tree species through planting or seeding; to provide forest habitat for species that rely upon edge and high-density, even-aged stands; and to mimic the effects of large-scale, catastrophic wildfires or hurricanes.

Conservationists, on the other hand, point to the detrimental effects of clear-cutting, since the practice can result in fragmented landscapes, landslides, increases in flammable "slash" left on forest floors, watershed degradation, habitat degradation and loss, soil erosion, soil temperature increases, aesthetic blight, species extinction, and loss of a forest's age and species diversity.

DOMINANT METHOD OF LOGGING

Clear-cutting, while financially efficient, a useful management tool, and historically a standard practice, is often applied to forests that do not benefit from the practice. During the 1970s, it is estimated that clear-cutting took place on more than 250,000 acres each year, or an acre every two minutes. On June 4, 1992, the U.S. Forest Service, in response to the public outcry against clear-cutting, announced it would reduce clear-cutting by 70 percent from 1988 levels. Yet clear-cutting remains the dominant method used for logging the U.S. national forests. Many bills have been introduced unsuccessfully in Congress to ban the use of clear-cutting in national forests.

Temperate rainforests in both the United States and Canada have experienced extensive clear-cutting, and it remains the major method used to fell forests. For instance, in the Canadian province of British Columbia, government-sanctioned clear-cutting is the dominant method of timber extraction for industrial purposes and the main cause of species endangerment for northern spotted owls; 70 percent of Vancouver Island has been clear-cut.

In underdeveloped countries, legal and illegal clear-cutting goes on unchallenged. Clear-cutting of tropical rain forests for wood exports and non-native tree plantations in Brazil, Congo, Indonesia, Malaysia, and elsewhere contributes to global warming and reduces biological diversity. According to the Rainforest Action Network, the world has already lost 80 percent of old growth forests worldwide, and less than 5 percent remain in the United States.

According to the United Nations, at least 37.5 million acres of rainforests are lost annually, an area the size of Georgia. Despite the relatively small land area they cover, rainforests are home to about half of the 5–10 million plant and animal species on the Earth.

SEE ALSO: Deforestation; Endangered Species; Forest Management; Forest Service; Habitat Protection; Rain Forests; Timber Industry.

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Clements, Frederic E. (1874–1945)

FREDERIC CLEMENTS WAS A founding figure in ecology, whose theory of plant succession helped consolidate the discipline in the early 20th century and continues to influence both scholarly and lay thinking about vegetation dynamics to this day.

Born in 1874 in Lincoln, Nebraska, Clements studied under Charles E. Bessey at the University of Nebraska, where he earned a bachelor's degree in 1894 and a doctorate in 1898. Surrounded by the rapid conversion of prairie to farmland, he conducted exhaustive inquiries into native grasses in the Great Plains, pioneering the use of the quadrat as a method of quantitative measurement of vegetation. His *Phytogeography of Nebraska* (1898, coauthored with Roscoe Pound), *Development and Structure of Vegetation* (1904), *Research Methods in Ecology* (1905), and *Plant Physiology and Ecology* (1907) established him as a leading figure in the nascent field of ecology, and in 1907 he accepted the post of Professor and Head of the Department of Botany at the University of Minnesota.

Clements expanded his fieldwork to the entire western United States, and in 1916 he completed his magnum opus, *Plant Succession: An Analysis of the Development of Vegetation.* The publisher, the Carnegie Institution of Washington, hired him away from Minnesota the following year and employed him until his retirement in 1941. Throughout his Carnegie career he worked summers at the Alpine Laboratory below Pike's Peak in Colorado; he spent winters at the Desert Laboratory in Tucson until 1925 and subsequently at a coastal ecology laboratory he established in Santa Barbara, California.

The central idea of Clements' theory was that units of vegetation he termed *formations* are "complex organisms" with determinate life histories. Each formation passes through a fixed sequence of "seres," or seral stages—e.g., lichens, annual grasses, perennial grasses, and trees—on the way to climax, at which point equilibrium is obtained between the vegetation, soil, and climate. Succession was the process by which formations developed through their stages. *Plant Succession* opened with the claim that this theory was "of universal application" and that it "represents the only complete and adequate view of vegetation." Four years later Clements published *Plant Indicators,* a companion volume on how to apply the theory to practical matters of agriculture and range management. Both books contained descriptions of the formations of western North America.

Upon Clements' death in 1945, A.G. Tansley wrote presciently that a theory "may be overstated, it may contain flaws which make it unacceptable in its entirety; but if it also contains, as Clements's did, a general idea of the first importance on which subsequent advance can be based, its originator's name can never be forgotten." During his lifetime, Clements's ontological claim for formations as organisms was strongly disputed, most scathingly by Henry Gleason in a 1926 journal article, "The Individualistic Concept of the Plant Association."

The field of range science, heavily indebted to succession, has struggled mightily to find an alternate theoretical paradigm; and in recent decades Clementsianism has become almost synonymous