FIFTH E.V. KOMAREK, SR. MEMORIAL FIRE ECOLOGY LECTURE

GLOBAL TRANSITIONS IN FIRE AND FIRE MANAGEMENT: RETROSPECTIVES AND PERSPECTIVES

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ABSTRACT

With changing demographic, socio-cultural, and economic conditions in the last 2–3 decades, wildland fire regimes are undergoing rapid changes worldwide. Increasing fire pressure on some regions and reduction of fire in others are noted. While perhumid tropical ecosystems such as rain forests or wetlands are subjected to more fire, other tropical vegetation (e.g., tropical savannas) burn less frequently because of desertification, intensive agriculture, pastoralism, and fuelwood use. Some temperate-hemiboreal and Mediterranean ecosystems of Europe, which culturally and historically co-evolved with fire, are threatened by fire exclusion. Human-caused wildfires in the boreal forest are increasingly replacing natural fire regimes.

Despite regional or zonal differences, 2 trends are leading toward the globalization of fire. First, the science community perceives fire as an important factor in the functioning of ecosystems, global biogeochemical cycles, and the atmosphere. Second, fire management approaches throughout the world are becoming mutually influenced through knowledge exchange and technology transfer.

A quarter of a century ago, the perception of fire in Central Europe, particularly in Germany, became influenced by the philosophy of fire ecology as espoused by Tall Timbers Research Station, Tallahassee, Florida. Since then, new concepts have been derived for regional Eurasian application, for transfer into the developing world, and for interdisciplinary fire research programs as part of research on global change. This paper describes selected examples of recent developments and changing paradigms in fire research and management as influenced by international cooperation.

keywords: fire history, fire management, fire research, fire science education, public attitudes, worldwide trends.

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INTRODUCTION

In the second half of the twentieth century, 4 major regions in the world could be distinguished by their distinctly different philosophies and technical approaches to forest protection and fire management: The Old World (Europe), the New World (North America) and Australia, the former Soviet Union, and the developing nations in the tropical-subtropical belts.

In the Old World, forest science and forest management policies had been influenced since the Middle Ages by the limitations of natural resources in the densely populated and intensively cultivated regions of Europe. These limitations would not allow any plant biomass to be lost to decay, pests, disease, or fire. Consequently, forest protection policies in Europe dogmatically imposed the elimination of natural and human-caused disturbances. The use of fire in swidden agriculture was completely banned by the middle of the twentieth century, as was silvopastoralism, considered detrimental to forest productivity. Nature conservation policies were governed by static concepts rather than by process-oriented objectives. This approach did not even change when socio-economic conditions and land-use intensity of the modern industrial societies began to dramatically influence the face of the European landscapes.

On the other side of the Atlantic Ocean, in North America, and in Australia, concepts of natural ecosystem and habitat management have a long tradition. Natural disturbance dynamics and manipulated disturbances such as prescribed burning are integral elements of natural resource management. However, the North American schools underestimated the significance and potential of European forestry, particularly aspects of silviculture and sustainable small-owner forest management.

At the same time, the largest forest region of the globe, located in the former Soviet Union, experienced an ideology-driven isolation from the rest of the world. Soviet forestry strictly practiced principles of forest protection by reduction or even exclusion of disturbance, although fire clearly had been an important factor in determining the structure and function of the boreal coniferous forest.

In the developing tropical world, rapid population growth and expanding national economies resulted in widespread forest degradation by uncontrolled utilization. Excessive use of fire in forest conversion and increasing occurrence of uncontrolled wildfires were the predominant driving factors in the destruction of the tropical forest. Despite the efforts of the donor community of industrial countries to support their former colonies by investing hundreds of millions of dollars in forestry projects, there is hardly any evidence of sustainability.

The importance of forests and disturbance by fire on the global system is a unifying theme for developing international land use and environmental policies addressing fire. A new era of information exchange among the 4 forest fire regions has begun and may result in innovative strategies in vegetation and fire management.

This paper investigates the changing paradigms in forestry and fire management in Europe, boreal Asia, and the tropics and how they have been mutually influenced by increased global awareness and transfer of science and technology.

GLOBAL PERCEPTION OF FIRE

The recent fire and smoke episodes of 1997–1998 in Southeast Asia and South America have received unprecedented attention by the global public. Previous large fire disasters, such as the recurrent fires in the wildland-urban interface in Australia and California, or large wildfires, such as the 1983 Ash Wednesday Fires in Australia or the Black Dragon Fire of 1987 in China (Goldammer and Di 1990), were relatively short events that disappeared from the memory of the public and the mass media as soon as they were extinguished. The large fires in Indonesia that burned several million hectares in 1982–1983 (Goldammer et al. 1996) and >14 million hectares in the former Soviet Union in 1987 (Cahoon et al. 1994) were hardly noted by the public. Only with the fires in Yellowstone National Park (Wyoming) in 1988 did a major and long-lasting scientific and public discussion on the role of fire in natural ecosystems begin.

The 1997–1998 fires in tropical Southeast Asia and South America lasted almost 12 months. The near-real time availability of fire and environmental data remotely sensed from space and their quick dissemination via the mass media and Internet made these land-clearing fires and wildfires a global issue. Discussion on the consequences of these fires is driven by the general public concern about threatened biodiversity and other ecological damage and the possible impacts of these fires on the "greenhouse effect" and global warming.

In the boreal and temperate zone of the northern hemisphere, however, the role of fire in forest and other vegetation management is taking new and different directions. Shrinking budgets of the forest services in North America and the Russian Federation have provided the impetus for consideration of new policies that possibly will allow natural and human-caused fires to burn within the ecological and economic limits to be defined.

In the Old World of Central and Northern Europe paradigms of silviculture and nature conservation are changing dramatically. Twenty-five years ago, at the Thirteenth Tall Timbers Fire Ecology Conference of 1973, European fire and nature conservation scientists had to meet in exile in Florida in order to openly discuss the use of fire in nature conservation (Makowski 1974, Tüxen 1974). It took a quarter of a century before the burning issue of restoring fire to ecosystem management of the European biota would be discussed (Goldammer et al. 1997).

It seems that the current trends of how fire is affecting the global landscapes and how societies re-

spond to fire are multidirectional and regionally different. The tropical world with its rapid population growth and increasing land use pressure experiences devastating fires of an unprecedented magnitude. In the sparsely populated boreal zone, forest managers are trying to define balanced fire policies aiming to satisfy both the ecological demands for fire as well as society's economic requirements and financial constraints. In the densely populated industrial countries in which fire historically had played an important role in maintaining the functioning of intensively cultivated landscapes, fire seems to be celebrating a comeback after decades of dogmatic fire exclusion.

EUROPEAN-NORTH AMERICAN FIRE RELATIONSHIPS

In this context it is interesting to highlight the role and importance of transatlantic relationships of forestry and fire management between Europe and America. In the beginning the flow of expertise was one-directional. Emigrants from Europe brought tremendous knowledge about the use of cultivation fires to the New World. European foresters tried to impose their philosophies of silviculture and sustainable forestry on America as they did in the rest of the colonial world.

The European fire users, especially the swidden agriculturists from northern Europe, met their indigenous counterparts, the Indian warriors and hunters who used fire as well. They might have found a common way of understanding through fire—if the European foresters had not succeeded with their dogmatic visions of disturbance-free forestry and silviculture. Indians and fire were the losers; the story was written by S.J. Pyne (1982) in his epic, *Fire in America.*

The exchange of philosophies in forest science came to a more or less complete halt during this century. After World War I and until the very recent post-World War II era there was little movement in North American forestry. With enough time and space between the New and the Old World, forestry in North America had been simplified to 2 categoric philosophies, industrial production forestry and museum-forest ecosystem management in national parks and wilderness areas. These diametrically opposed approaches satisfied both the demands for wood-based consumer products and the leisure requirements of a post-modern industrial society.

Between these extremes, however, the fire issue began to take over the role of a catalytic link between the philosophies of industrial forestry and ecosystem management. Both sides, the profit- and market-oriented managers and the ecologists, recognized that fire was the missing link between the seemingly incompatible positions. Industrial foresters found it in their interest to accept the concepts of modern (fire) ecology. For instance, using fire was compatible with the goal of creating mono-structured stands of conifers and keeping out the less profitable hardwoods. Fire ecologists celebrated victory.

In Europe, meanwhile, fire became forgotten. Instead, foresters attempted to practice advanced silviculture to meet the demands of the industrial societies, which were limited in space. Silviculture systems were invented that imitated natural gap disturbances. *Plenterwald* (selection system) and *Femelschlag* (irregular shelterwood) were nothing more than a compromise between the production needs and aesthetic demands of a romantic society; clear-cuts were stigmatized in favor of selective cutting.

At the end of the twentieth century the transatlantic exchange of forestry and vegetation management concepts is becoming bi-directional. North American foresters are looking to the Old World, eagerly attempting to learn from those who have been limited by resources. Conversely, European nature conservation administrators are trying to learn from the New World experience in wilderness ecosystem management. A German forest scientist, M. Weber, who is contributing to this Twenty-first Tall Timbers Fire Ecology Conference, is now a leading Canadian fire researcher. S.J. Pyne, an American environmental and fire historian who presented the last E.V. Komarek, Sr. Fire Ecology Lecture, wrote the European cultural history of fire, *Vestal Fire* (1997). In Europe, Mediterranean and Nordic fire researchers take advantage of the methodologies in fire research and management that were refined in North America while Europe was in fire dormancy.

RETROSPECTIVES ON GLOBAL FIRE: THE 1970's AND 1980's

The most important time of my education in forest sciences was my study at the school of fire ecology at Tall Timbers Research Station, under the guidance—not to say emphatic indoctrination—of E.V. Komarek Sr., the pioneer of fire ecology. In the winter of 1974–1975 I caught the spirit, reinforced it at the occasion of the 1976 U.S. Department of Agriculture, Forest Service, symposium "Fire by Prescription," and brought it back home to Europe. I had to recognize, however, that the timing was premature for Europe. Nevertheless, besides my own work, I began to convene the first series of fire ecology workshops in Europe, starting with the First and Second Fire Ecology Symposium held at Freiburg University in 1977 and 1983 (Forstzoologisches Institut 1978, Goldammer 1978, 1983*a*). Under the sponsorship of J.-P. Vité, professor of forest zoology and dean of the faculty of Forest Science at Freiburg University, I sought to convene all European fire researchers and managers interested in new approaches in fire science and management. In those years fire research in the Mediterranean region was already maturing while Central and Northern Europe were not yet ready. This situation did not even change after the large wildfires in Germany in the dry summers of 1975 and 1976. Komarek's advice to German foresters was ignored by the monolithically dogmatic forest service and nature conservation administrations.

This was a clear signal to me to take my fire phi-

losophies and emigrate. I went to the tropics and subtropics, the most diversified fire belt on Earth. I recognized that in the context of modern fire science, little attention had been given to the region where, from a global perspective, most fires are burning. Twenty years ago virtually nobody from the international fire science community was interested in the tropics.

The Tropical Fire World

During my first exploratory expedition to southern Brazil and Amazonia in 1976, the precursors of the upcoming fire problems could be seen already. For the public, however, the large-scale burning of Amazonian rain forests remained undetected. Even the large wildfires in Borneo during the 1982–1983 El Niño episode, which affected about 5 million hectares of primary and secondary forest and other vegetation, were hardly noted (Goldammer and Seibert 1990, Malingreau 1990).

We started to work intensively in tropical fire research in the early 1980's. At that time our primary attention was on plantation forestry. Huge areas of exotic forest plantations, predominantly fast-growing pines and eucalypts, were set up all over the developing world. Southern Brazil was one focus area where forest managers planted time bombs: highly flammable tree plantations consisting of species that in their natural environment had co-evolved with fire. Plantation forestry attempted to grow them by fire exclusion. Thus, my work ironically began with bringing fire to the tropics (Goldammer 1983*b,c,* de Ronde et al. 1990).

However, soon I began to recognize that the burning problems arose where humans penetrated into the most vulnerable sites, the mountain forests and the lowland rain forests. Very much to our surprise, we found a variety of vegetation types on large areas that had co-evolved with humans and fire. Although it was already well known and well studied that the global tropical savannas had been shaped by natural and human-caused fires for millennia, there were quite interesting latitudinal and altitudinal gradients in fire and forest development.

When I started my work in tropical South Asia in the mid-1980's, I encountered a distinct fire belt in the mountains all over the region. Long-time fire impacts were manifested in extensive fire ecosystems consisting of fire-tolerant native conifers (pines) at the expense of hardwoods. Up to a certain degree tropical pines can cope with environmental and land use stresses, such as drought, shallow soils, erosion, grazing, trampling, and fire. Rapidly increasing pressure and multiple stresses through indiscriminate forest use, however, increasingly led to the deterioration of these forests (Goldammer and Peñafiel 1990).

The forest zone between the tropical savannas and the equatorial rain forest is another prominent fire belt. Savanna forest, dry forest, deciduous forest, or monsoon forest—these are terms that generally describe a tropical forest subjected to regular seasonality in rainfall and strongly associated with fire during the dry seasons (Stott et al. 1990). Like savannas, they are burned almost every year, mainly by surface fires spreading in the grass-leaf layers of these open forest ecosystems. Fire-tolerant trees dominate this fire environment. Fire exclusion leads to the restoration of fire-sensitive species and a more species-rich forest composition.

What was so intriguing was that these fire-climax forests seemed to offer a carrying capacity for humans that was higher than the fire-excluded, disturbance-free climax variant. Fire-selected pines and dipterocarps are useful for timber production; the open forests offer shaded grazing resources and provide a wide range of non-wood forest products stimulated by fire.

What was so discouraging, however, was that too much pressure from rapid land conversion, increased livestock density, and uncontrolled fire was destabilizing these forests. Most threatening seems the fact that the unified force of humans, cattle, and fire drove its spearheads into the rainforest. In the early 1980's the first warning signals from the rainforest went unheard.

The picture changed in the second part of the decade. The rate of rain forest conversion in Amazonia accelerated so fast that the land-clearing fires could not be overlooked from space (Kaufman et al. 1990). Spaceborne remote sensing technologies in fact brought about the change of perspective. Forest destruction became apparent despite national governments' attempts to hide it.

With these impressions in mind, I thought that we should make this hidden process visible to the fire science community and the policymakers. I called for the first global tropical fire symposium, again at Freiburg University, in 1989. Besides compiling the first comprehensive analysis of global tropical fire (Goldammer 1990), the participants of the conference, "Fire in the Tropical Biota," drafted the "Freiburg Declaration on Tropical Fires" (Goldammer 1990:Appendix), which we brought to the attention of politicians and policymakers. Yet it still took about a decade for the international policymakers to respond.

Meanwhile, however, the fire science community decided to go ahead. In 1990 the foundations were laid for a series of large regional fire research programs at subcontinental, continental, and even intercontinental levels. The International Geosphere-Biosphere Programme (IGBP) provided the umbrella for international and interdisciplinary fire research programs. Under the frame of the Biomass Burning Experiment, a subprogram of the International Global Atmospheric Chemistry (IGAC) project, the first (and still largest) project was designed to investigate the atmospheric chemical consequences of fires in tropical and subtropical forests and savannas of South America (Brazil) and southern Africa (Andreae et al. 1993). The Southern African Fire-Atmosphere Research Initiative (SAFARI)-92 was the first intercontinental fire experiment. With its field phase in 1992, this 6-year project involved >150 fire researchers from 14 nations (JGR 1996, Van Wilgen et al. 1997). The results revealed, among other things, that fires on both sides of the tropical Atlantic are the reason for a large seasonal hemi-

spheric event, the elevated ozone concentrations in the troposphere during the dry season (Aug–Nov). Between 1994–1997 additional international fire research campaigns were launched in near-equator Africa, particularly in the Central African Republic, Congo, Zambia, and Kenya. Other projects were conducted in the 1990's in South America, predominantly in and around the Amazon Basin.

The experiments of the 1990's were preceded by the first attempt to produce a review of the role and impacts of vegetation fires at the planetary scale. The Dahlem Conference, "Fire in the Environment—the Ecological, Atmospheric, Chemical, and Climatic Importance of Vegetation Fires," held in Berlin, Germany, in 1992, assessed the state of knowledge, identified needs, and developed concepts for an integrated global fire science approach (Crutzen and Goldammer 1993).

The Burning Taiga

At that time the walls between East and West had been taken down. For the first time we got a full view of fire in the largest forest in the world. Before the end of the Cold War there had been speculation on fire in the Soviet Union, but with little evidence of the truth.

In 1991 S.J. Pyne and I went on the first post-Cold War fire tour of the Soviet Union, several months before the Communist empire fell apart (Pyne 1992). We quickly recognized we had entered a world that had been separated philosophically from the rest of the world for >7 decades. Fire was evil number one in this billion-hectare forest. With the largest paramilitary fire-control force on the globe, the Soviets had suppressed what had been a vital element of the forest—fire, which had shaped the endless and productive taiga forest.

In 1993, only 2 years after the first East-West contacts by fire specialists, we went to work. After the initial joint brainstorming in Krasnoyarsk, the center of Siberia's forest and fire research, we produced the first analysis on "Fire in Ecosystems of Boreal Eurasia" (Goldammer and Furyaev 1996). Then we went to the field. The "Fire Research Campaign Asia-North" (FIRESCAN) conducted its first joint experiment in the heart of Siberia, with the participation of scientists from all boreal nations (FIRESCAN Science Team 1996).

The "Bor Forest Island Fire Experiment," in which fire and atmosphere researchers from all nations of the boreal zone participated, opened a scientific dialogue with the forest services. The main long-term objective of the dialogue is a new fire policy that will consider the ecological role of fire in the taiga and tundra ecosystems, meet the overall goals of sustainable forestry and silviculture, and prepare forest managers to deal with possible effects of regional climate change. Politically this process was shielded by the North Atlantic Treaty Organization (NATO), which with its scientific branch had peacefully entered Russia in 1993, attempting to define new mechanisms of science collaboration between East and West (e.g., Goldammer and Furyaev 1995).

BUILDING THE BRIDGE FROM FIRE SCIENCE TO MANAGEMENT AND POLICIES

Fire in the Microcosmos of Nature Conservation and Landscape Management in Europe

In Europe we meanwhile have gone through a major change of paradigms in nature conservation. Some recent developments in nature conservation are shaking the foundations of German landscape management. Interestingly enough, this is happening at the time of the publication of S.J. Pyne's (1997) comprehensive analysis of the cultural history of European fire, in which he writes: "Europe's peculiar geography and dense demographics, and the intensity of its agricultural reclamation, gave European fire a special character. Europe's temperate core—not shaped by well-defined fire season—granted humans an unusual degree of control over fire, and encouraged the belief that fire was, in principle, a strictly human agency, that it was a convenient tool but not an essential process." Furthermore, Pyne (1997) states:

> Germany is a controlled landscape. It has to be, given its population pressures. The German nature reserves constitute only 1.1 percent of the national landmass, with 200 of them less than 5 hectares in size, other restricted landscapes amount to18 percent. None tolerate fire. Even outside these zones, agricultural burning is rigorously proscribed to specific seasons. The burning of hedges, in particular, has aroused strong condemnation over the centuries because it breaks down the careful borders of political and propertied world, another illustration of fire as manifestation of social disorder. That perception describes perfectly the difference between landscape organized as a house instead of an ecosystem.

His statements are right. In the very geographic center of Europe—in Germany—post-World War II development continued to eradicate elements vital to the cultural heritage of landscapes and to biodiversity. The cultural landscapes and vegetation patterns of Central Europe are the result of hundreds of years of intensive use of the land. Cutting, mowing, grazing, and burning were used for harvesting timber and fuelwood; improving site conditions; and raising domestic livestock by stimulating and regenerating desirable grasses, herbs, and bushes and by removing undesirable, moribund, and dead plant biomass. Like elsewhere in the world, our ancestors practiced slash-and-burn methods that had a similar physiognomy all over Europe and followed principles similar to the swidden agricultural systems of the tropics.

In Germany, systems of rotating swidden agriculture were part of a forest utilization cycle known as *Reuteberge* (*Rüttibrennen*), *Birkenbergwirtschaft,* and

Haubergwirtschaft (local names for slash-and-burn agriculture), which created a mosaic of forest, open grazing, and agricultural lands, with all the successional stages in between. Within the Black Forest region in southwestern Germany, swidden agriculture was practiced on approximately 70,000 hectares by the middle of the nineteenth century. After World War II, ca. 1950, this system was still alive on approximately 10,000 hectares.

Regular burning of juniper grasslands in southern Germany and on *Calluna* heathlands in northern Germany was very common until the late nineteenth century. The intensive use of heathland for sheep grazing and the use of raw humus for stables and for fuel created nutrient-poor sites. These sites, however, provided ecological niches—habitats—for a variety of plant and animal species.

Ignoring the fact that Central Europe's face has been shaped by traditional practices in agriculture, pastoralism, and forestry over hundreds of years, nature conservationists and landscape planners attempted to preserve this heritage by excluding land use methods. The creation of completely protected refugia for nature, embedded in a rapidly growing post-modern industrial society, was built on the belief that the preservation of nature and biodiversity could be reached only with the exclusion of all disturbances. This policy soon turned out to be a misconception. The heathlands of northern Germany, rich in biodiversity and popularity, as portrayed by the romantic writer H. Löns, began to change: With every hectare abandoned by sheep and shepherds' fires, the forest reconquered the terrain. Monotonous pine forests began to replace the flowering heathlands.

This misconception became visible on a large scale with the changing socio-economic conditions of post-war Europe and the increasing influence of European and global markets on the national agricultural sector. High production costs—as compared to the competitive international economies and markets—and incompatibility with the demands of a modern industrial society led to a dramatic decrease in the use of vegetative matter. While a similar process in the Mediterranean countries provided fuel for more and more intensive wildland fires, afforestation of abandoned farmlands became a regular practice in rural Germany. Only a restrictive practice of issuing afforestation permits halted the tendency of steadily growing forest cover and the loss of variety in traditional landscape patterns. Abandoned sites that landscape architects wanted to keep open, e.g., for recreation (hiking, skiing), had to be at government expense. Mowing, mulching, and grazing in accordance with landscape plans, however, soon became prohibitively expensive.

Ironically, all this became most visible at the end of the Cold War. The process of reducing military forces stationed on German territory set free a tremendous amount of surplus land. Large military exercise areas in former East and West Germany were abandoned and put under nature protection laws. With the retreat of the military exercises, gunfire, and maneuvers, the disturbances disappeared. Soon it was recognized that the impact of fire and heavy vehicles had been most important in stopping succession, creating new succession opportunities, and producing a mosaic of vegetation patterns rich in species. In other words: With increased protection and the exclusion of disturbances, diversity began to decline.

Increasing costs for large-scale landscape gardening all over Germany and the dramatic challenges of vegetation use on former military areas, marginal sites and steep terrain, and extremely small patches (e.g., hedge strips between intensively used agricultural and viticultural sites)—important refugia for species that could not survive in the chemo-technical environment of industrial agriculture—all created new discussions about maintaining the cultural heritage.

It was only about 2 years ago that ecologists and nature conservationists in Germany began to think about restoring the use of fire in those landscapes that had been treated with fire historically and that were threatened by the exclusion of all disturbance. Between 1996–1997, a fire revolution swept over the offices of the public administrations and the media. While the public is troubled by the sight of threatening smoke coming out of Southeast Asia and local farmers are still punished for the illegal use of fire, fire scientists began to sort out the pros and cons of restoring fire to maintain biodiversity and landscape aesthetics. Within <1 year, 4 scientific workshops were held at the State Academies for Nature Conservation in Lower Saxony (Alfred Toepfer Akademie 1997), Hesse, and Baden-Württemberg. Finally, in August 1997, the Federal German Nature Conservation Academy held a workshop on "Restoration of Dynamic Processes in Nature Conservation," in which fire was a key issue (Bundesamt für Naturschutz 1998). In 1997 the first large prescribed burning research program began in the state of Baden-Württemberg, aiming to investigate the use of prescribed burning in the management and maintenance of seral-stage habitats in the viticulture region of southwestern Germany. The use of fire to maintain or restore grass cover, a habitat for endangered flora and fauna, is the objective of this program, which is driven by the dramatically increasing costs for subsidized landscape gardening and the fact that many of the ecologically vulnerable sites have been lost due to succession towards bush and tree cover.

The changing paradigm in nature conservation in Germany is evident. The signals emitted by nature conservation fires clearly show that the fire ban imposed on German landscapes in the mid-1970's can no longer be upheld. The solutions, however, must consider the manifold sensitivities of an industrial society, in which a high awareness of environmental issues determines day-to-day politics.

Eurasia's Macrocosm of Fire

Eurasia seems to be on the same track as Germany. The Federal Russian Forest Service is now considering a new fire management policy. It will be based on several facts ignored by the forestry *Nomenklatura* (the governing class of the former Soviet Union) for

nearly a century. First, in Siberia, in the largest forest block on Earth, most wildfires are running as surface fires. More than 15% of all fires are started by lightning; in some regions, even up to 50% are lightning-ignited. Many forest types are adapted to fire, yet are economically productive and ecologically rich and stable.

Instead of following an outdated fire control policy, Russia may now have to go towards an Integrated Forest Fire Management System, which would include a prescribed natural and human-caused fire policy, and prescribed burning programs. A dogmatic policy will be replaced by a sophisticated fire intelligence and information system that must rely on well trained personnel, a fire-related inventory of forest resources, and the availability of information in order to cover the vast Eurasian continent. Currently a European Union-funded Technical Assistance to Commonwealth of Independent States (TACIS) project is underway (1999–2000) to support the establishment of a new forest-fire management system in Russia (TACIS 1999).

The Federal Russian Forest Service's strategy for managing fire on >1 billion hectares of forestland must take into account the possible environmental changes of the near future. Until now, Russian fire managers have been faced with the consequences of inappropriate forestry practices, e.g., large clear-cuts and wrong selective cutting methods, industrial contamination, and the effects of nuclear fallout from fires in radioactively contaminated terrain.

In the near future, the climate probably will change, particularly in continental (central) Siberia. Like the continental "dustbowl" of the United States and the boreal zone of Canada, central Siberia will be most affected by regional climate change. Prolonged summer droughts will lead to more frequent extreme fire seasons (Fosberg et al. 1996, Stocks et al. 1996), with dramatic impacts on the fate of forest cover and—most critically—its underlying permafrost. The disturbance of old equilibria between climate and forest fires may lead to the widespread disappearance of eastern Siberian larch forests, the melting of permafrost, and the release of paleo-greenhouse gases that have been preserved in the ice for millennia. Additionally, hundreds of gigatons of carbon stored in Siberian swamp ecosystems may be released by fire once these ecosystems begin to dry out in the predicted long and hot summers of the next century.

However, the challenges are not only in the boreal zone. The fires in Indonesia and Brazil in 1998 suggest that these regions will continue to be hotspots of large-scale environmental disasters (Goldammer 1999). The future environmental and socio-economic development in the so-called "Maritime Continent," the region encompassing the archipelago of Indonesia, more than ever before will be determined by the impacts of El Niño. Global circulation models, based on coupled atmosphere-ocean models, predict an increase in the recurrence and severity of El Niño events within the very near future.

GLOBAL COOPERATION IN FIRE MANAGEMENT

For many years there was very limited interest in international cooperation in fire management and policy development. While some bi- or multilateral agreements had been reached (e.g., to provide mutual fire emergency assistance along common territorial borders), there were virtually no mechanisms in place to share information about fire, develop fire management strategies, or address fire through internationally acceptable policies or binding agreements.

The situation has recently changed, mainly as a result of the fire and smoke-haze episode in Southeast Asia in 1997–1998. The extensive smoke pollution, which affected >40 million people in Southeast Asia, has created a new awareness of transboundary and global fire issues. Several agencies and programs of the United Nations (the Food and Agriculture Organization [FAO], World Health Organization, World Meteorological Organization, United Nations Environment Programme, and the International Decade of Natural Disaster Reduction, supported by the UN-Team of Specialists on Forest Fire of the FAO and the Economic Commission for Europe), the international banks (notably the German Bank for Reconstruction, the World Bank, and the Asian Development Bank), and non-government organizations (e.g., the World Conservation Union) are now actively collaborating on international fire issues.

The establishment of the Global Fire Monitoring Center (GFMC) reflects a new trend. The fire science and technology community is now beginning to share with the users the wealth of fire information available in archives and publications and through spaceborne sensors (*http://www.uni-freiburg.de/fireglobe*). The GFMC offers a communication platform for those who want to learn about, transfer, and import ideas and expertise on fire and fire management.

CONCLUSIONS AND OUTLOOK

At the end of the 1990's we recognize several new trends in global fire. Fire regimes are undergoing changes driven by the coupled effects of human population growth, land use change, and climate variability. The socio-economic disparities between nations, the common global interest in the protection of natural resources from damaging fires, and the need to promote sustainable fire management practices require greater international collaboration. During the last decade scientific and technical cooperation worldwide has increased.

Industrial nations like Germany and other European countries are currently not exposed to fire problems of a magnitude comparable to that of developing nations. However, they are increasingly involved in technology development and transfer. Priorities include the development of new, dedicated spaceborne fire sensors, fire management information systems, and decision-support tools. Scientific initiatives, such as under the scheme of the IGBP, are designed as part-

nership programs that involve participation in research campaigns and institution-building.

Technology transfer to the field level is implemented by a steadily increasing number of bilateral and multilateral technical cooperation projects in fire management. Most projects initiated in the 1990's have focused on prevention and operate at the community level. However, the technological components increasingly include advanced remote sensing systems and appropriate communication tools.

These new approaches in global cooperation in the field of fire are no longer based on single, national, or potentially otherwise biased philosophies and methods. Instead, they have been influenced by a learning—giving and taking—process at the international level.

On a personal note, I started my professional career as a student at Tall Timbers Research Station in 1974. After learning the basic lessons of fire ecology, I looked for new applications in the yet less-explored world of fire. For all of us the learning process has never ended and thus has fostered a better understanding of the nature of global fire.

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