GIS and Remote Sensing for Wildland Fire Suppression and Burned Area Restoration

Jerry D. Greer

It is not common in the western United States to see the sun rise every morning, week after week, holding a deep red color. Under more favorable conditions, the sun jumps blazing white over indigo blue mountains and crosses a deep blue sky. As seen by humans in their relatively short lifetimes, the summer of 1994 was not normal and the daily crossing of the red sun confirmed this belief. The sun took its ruby red color from the smoke rising from several very large wildfires burning in the west. Literally hundreds of wildland fires burning in forest and grasslands affected thousands of acres of forest, brush, and glasslands. These large fires sometimes burned hot and fast. Flame heights of 200 feet were reported by fire observers. Such fires stretch the resources of fire fighters to the maximum.

McCall, located in central Idaho, is like many small communities in the Pacific Northwest. But when wildfires come to the surrounding forests, the local population of 2500 can swell to several times that number as specialists are brought in to help suppress and control the fires. Hundreds of people build firelines to break the continuity of fuels which can carry the fire into new areas. Overhead, air tankers and large helicopters deliver fire retardants knocking down hot spots. Support people and management teams provide fire fighters with all the supplies and equipment they need to be effective.
Some of those who come to help fight the fires are technical people who help use the latest technology to make fire suppression safer and more efficient. One major problem for fire fighters is to determine how a wildfire will act and how it may threaten life, property and wildland resources. Because fuels (which include standing and down trees or brush and grass) are found in various concentrations and distributions, the control and management of wildfire is a complicated task that becomes even more complex when weather influences are considered. It is in this arena that remote sensing technology and geographic information systems are playing an increasingly important part.

Traditional Methods and Experimentation

Advanced technology is used in fire suppression because the very high values of resources such as wood and clean water; and the overall health of ecosystems coupled with more threats to human life place tighter restrictions on managers. Since time is of the essence, managers need more accurate information in shorter time periods. In the early 1920s, forest managers quickly saw the potential of aircraft and they have been used continuously and extensively for aerial observation since. A tradition of trying the latest technology continued and soon after the invention of television, members of the Forest Service, Department of Agriculture, experimented with television as a replacement for fire lookouts. Today, foresters and resource managers on both public and private lands routinely experiment with and use remote sensing and GIS technology to find alternative solutions to fire suppression problems.

The nature of fire

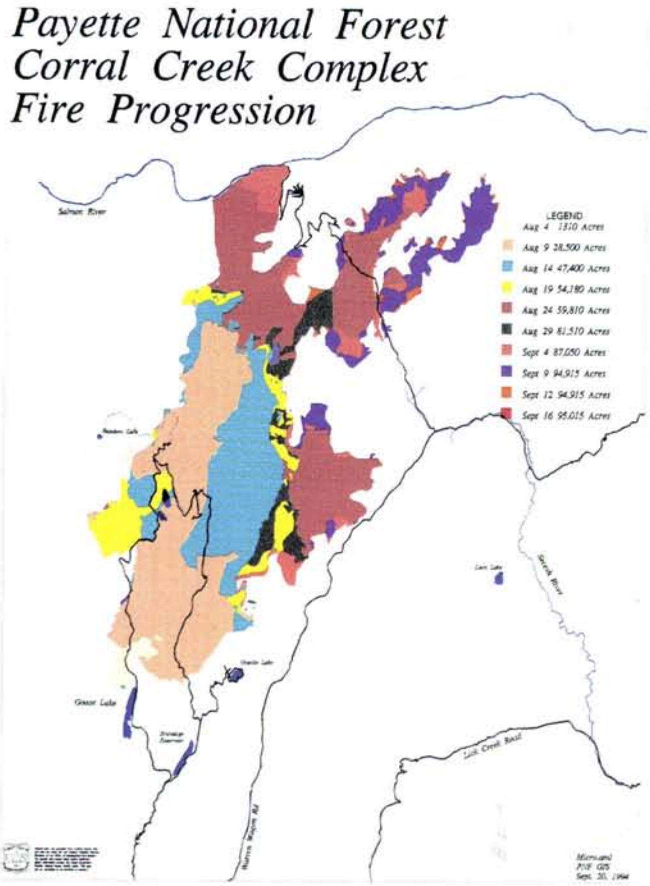
Wildland fire suppression is not a simple task and the effects of fire are far from simple. For example, forest fires do not typically destroy everything in their path. In fact, much of what happened this summer in Idaho appears to be more in line with the natural occurrence of fire. These lightning-caused fires burned in a mosaic pattern; some areas burned completely while others were not touched at all and, there are all classes of burn intensities in between. It may come as a surprise to learn that for some, understanding what

> **...the summer of 1994 was not normal...**

happen during the fire is as important as suppressing the fire is to others. Both remote sensing and GIS have a part in both.

Many forest resource managers now believe that we must be more active in our efforts to maintain healthy ecosystems. This requires a better knowledge of the characteristic of forest ecosystems, of the distribution of fuels available to wildfires, and of the aftermath ecology of large fires. Much of our understanding of these things will come from the use of data collected by remote sensing technology in the GIS environment.

It is critical that we gain some specific knowledge in certain areas. For example, there is an urgent need to better understand the complicated wildland-urban interface and the risks associated with people living in scattered dwellings built within areas of highly flammable forest and brush fuel. Remote sensing and geographic information sys-



tems will help with understanding and with planning. But after the fires have started, it is too late for planned development; there is only time to respond to the emergency.

There are two phases in the management of a wildland fire when remote sensing and GIS can be of benefit. The first phase is during the time when the fire is uncontrolled, the second phase is after the fire is out. On the Payette National Forest, we were monitoring conditions and suppression efforts on three major fire systems; the Corral Creek Complex, the Blackwell Complex, and the Chicken Complex. (Traditionally, fires are often named after a local topographic feature, hence the sometimes unique and colorful names. The term "complex" refers to the fact that each of these large wildfires had starts from multiple lightning strikes each of which started a small fire. When these smaller fires burned together, the resulting larger fire became a complex.)

...management of wildfires is a complicated task...

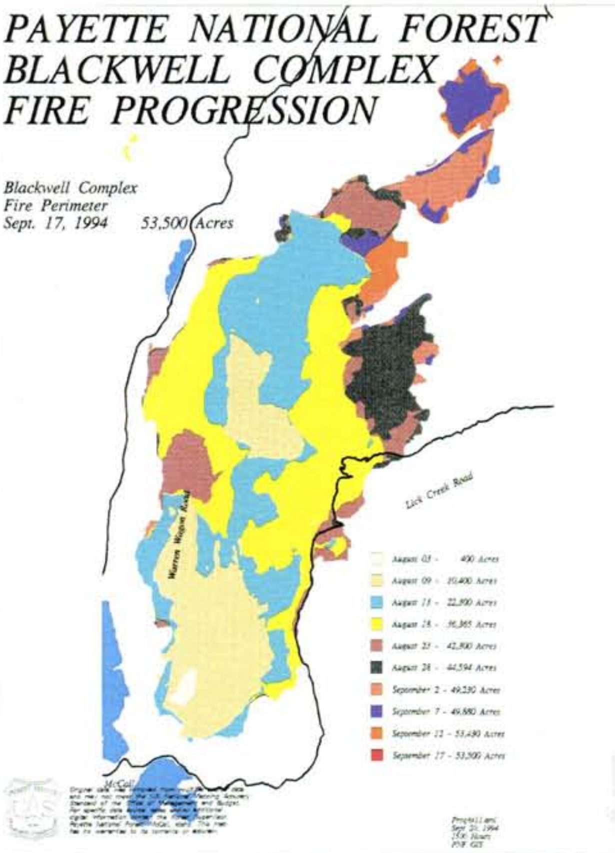
Remote sensing in action

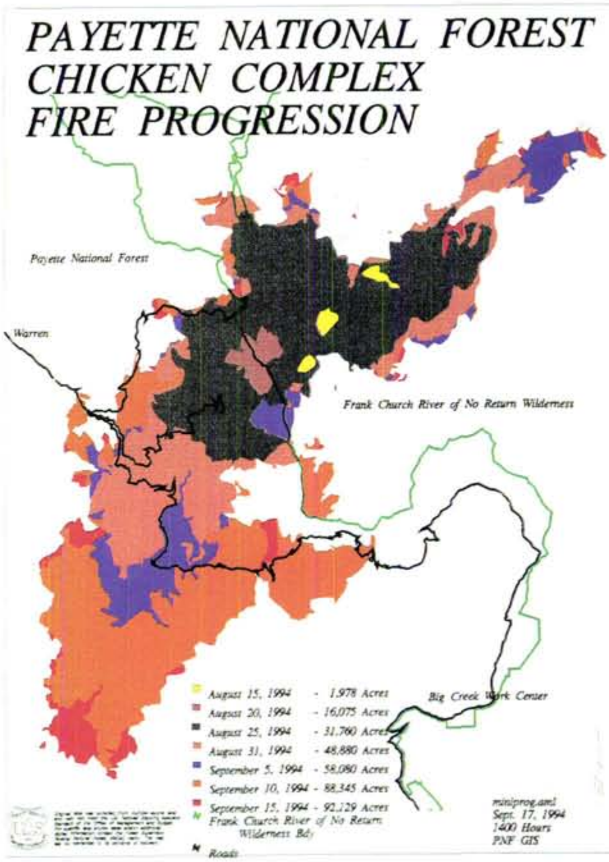
When a fire is moving fast under dry and windy weather conditions, fire suppression teams need accurate information fast. Such data has traditionally been supplied by aerial observers in helicopters and fixed wing aircraft or by scouts who walk the area searching for indications of problems and opportunities. Information is relayed either by radio or by passing paper notes and maps to the suppression team planners. One of the first routinely used remote sensing devices applied to data acquisition on wildland fires is the thermal infrared line scanner. Fire fighters call overflights carrying this instrument "infrared flights" and today, they routinely anticipate the availability of interpreted imagery on almost every large fire. Flights are made during the early morning, predawn, hours of the day to take advantage of the difference between cooler surface temperatures of the earth and the heat produced by the fire. Images of heat sources are studied and relevant information is transferred to paper maps. These maps become the foundation of tactical plans for suppression teams.

Other remote sensing technology is used in support of suppression efforts. Global Positioning System (GPS) equipment is carried in aircraft and by ground forces to precisely locate the fire perimeter and to locate problem areas that would later need special attention by "hotshot crews" of fire fighters or by air tankers delivering fire retardants. To prepare fire perimeter maps, we used three data sets; GPS, thermal infrared interpretations, and hardcopy, field maps prepared by fire fighters on the ground as they made progress. The data sets were analyzed by fire team planners and they produced a single manuscript which we subsequently digitized for our GIS work.

We also utilized helicopters carrying color video cameras, FLIR, (Forward Looking InfraRed) scanners, and GPS. These reconnaissance aircraft supplied ARC/INFO files of the fireline location along with video images that showed the conditions on the visible perimeter of the fire. Usually, the head or leading edge of the fire was producing so much smoke that flights could not be made over them, so complete coverage from this platform was sometimes not available.

One of the first looks we took of the fires on the Payette National Forest from a nontraditional remote sensing platform was through the AVHRR or, the Advanced Very High Resolution Radiometer. Resolution (on the order of one kilometer pixels) is fairly coarse. The images, therefore, had some value as public information displays and very little (if any) value for tactical suppression teams. Images were produced and displayed at public meetings and they prompted many questions. For the Payette staff, it was a start — and it caught the attention of fire fighters and the public. It was also of interest to the GIS staff and they quickly expanded their interest into more detailed applications of remote sensing and GIS.





GIS Support to the Suppression Teams

When large fires burn close to communities, one of the critical duties facing fire and resource managers is to provide timely and accurate information to the citizens who are most directly affected by the fire. One way the Payette staff addressed this problem was by preparing and displaying maps and perspective views of the fire area. People could easily see where the fire was in relation to well known landmarks and to their homes.

Perspective views of fire areas were produced in GIS using ARC/INFO software running in the Unix environment on IBM RISC/6000 work stations. Digital elevation models were used to produce the prospective views over which current fire perimeters were draped. Landmark names were added and the display effectively showed viewers how the fire was spreading over the mountainous topography.

The first product we produced for suppression teams was suggested by one of the suppression planners who had a basic understanding of GIS. He requested a simple mylar overlay showing the daily location of the fire perimeter coded to indicate if it were constructed by hand tools or by tractors. He also requested that the locations of water sources, helispots, and "drop-points" be shown and annotated. We prepared the overlay as manuscripted by his team and then updated it daily as new information came in. We made daily calculations of fire areas and archived the data for future use. The suppression team laid this overlay on a detailed hardcopy base map and prepared shift assignment maps from the two data sets. While partly a "bookkeeping" function, these simple overlays proved to be of great value because the suppression planners could get shift plans out faster and with much greater accuracy.

understanding what will happen during the fire is as important as suppressing the fire...

Another product we furnished to suppression teams were maps illustrating periodic fire perimeter changes. We kept daily track of the fire line changes but for the display, we produced maps showing spread by five-day blocks of time. Color coded, the maps clearly showed fire managers how the fire was progressing. These maps also have long life value because they become an important part of the fire history file that our staff will use for the next 5 to 10 years in project work.

To show fire suppression planners how the fire was spreading in relation to forest stand conditions, we prepared a map to

fire suppression teams need accurate information

display timber inventory data over which we laid the current fire perimeter. Different stands of trees were color coded and the map was supplied with ancillary data describing the characteristics of the timber stands. Fire suppression planners could then see and understand fire behavior in relation to the fuels being consumed by the wildfire. We soon found that they could make educated guesses about the probable spread of fire and were using the data to plan the best location of fire lines. We added an overlay of DEM based contour lines and the use of GIS maps took on a new dimension. With this added information, planners could now locate fire lines in relation to topography and less hazardous timber stands. In fire suppression, fire lines are located for crew safety and control effectiveness. Fire lines were planned, for example, to follow topographic features and to take advantage of forest areas with less fuel. Suppression planners could also use conventional aerial photography with the forest stand data and take advantage of rock and meadow areas for the construction of fire lines.

We made an attempt to provide suppression teams with data about their projected fire control lines. Using the capabilities of GIS we computed the length of planned fire lines and provided a topographic profile to help with estimates of rates of line production by crews. This was not very useful and we dropped it from our service.

Maps and assessments that were being currently produced by the GIS staff were also used during the control phase by special oversight teams. These groups of experts in fire suppression made hot-fire critiques. These are so called because the ongoing fire suppression effort is evaluated to ensure that the local efforts are well founded in fire suppression theory and that decisions about suppression tactics are safe and effective. Recommendations are made in midcourse if needed to keep the suppression effort on the most effective track. All GIS products were used to inform the teams about fire history and to demonstrate how advanced technology was being used by suppression teams.

After the fire is out

Even as fires continued to burn to the northeast, scientists were already looking at the cooler southern parts to see what had happened to forest resources. GPS units carried by field teams are used to determine precise locations of study plots that must be revisited over the next several years as we observe how vegetation and wildlife comes back into burned areas. Teams of specialists in soils, vegetation, hydrology, wildlife, and information management work together to recommend rehabilitation actions that should be immediately implemented. These recommendations address restoration needs that will be required to protect critical watersheds from erosion. The scientists assigned to this phase of the study need three pieces of information; soils, slope and aspect classifications, and burn intensity.

they could make educated guesses about the probable spread of fire

Also, the Payette National Forest Ecosystem Overview Team will be studying long-term impacts of fires on affected ecosystems and will plan treatments to prevent resource damage, to use fire killed timber, and to ensure that affected landscapes are maintained in a productive and healthy condition. Remote sensing data, image processing with ERDAS software, and GIS procedures will be used to provide support for management decisions.

An immediate need for data is being satisfied by a flight of NASA's ER-2 high altitude reconnaissance aircraft. This research and development overflight will cover about 300,000 acres of land on the Payette National Forest that have been affected by the fires. On a single day, in a narrow 3 and 1/2 hour window during mid-day to early afternoon, the ER-2 will carry the Thematic Mapper Simulator (TMS) and one RC-10 camera with Kodak 060 color infrared film. The 1:60,000 scale photography will be used by NASA, Ames Research Center, to prepare burn intensity maps to be used for our first detailed damage assessments. The TMS data will be used for a variety of purposes in our rapid assessment of impacts and for the longer term, the data set will be used used for subsequent change detection studies and other projects in ecosystem evaluation and management.

Several other projects are underway as this goes to press. We are acquiring Landsat Thematic Mapper data to evaluate changes brought by such extensive wildfires. This data will be used to study vegetative changes over the landscape. Our plan calls for combining data from a fall of 1993 TM image with data from a scene in September of 1994 to do a change detection study and vegetative classification.

Tree-ring studies of fire history will continue and data will be used in our ecosystem assessments to compare pre-european settlement fire patterns with current patterns. This will help us understand the part natural fire plays in central Idaho ecosystems.

Lessons learned

First, GIS can be a useful and economic tool in support of fire suppression and post fire assessments. Much of the data we need for our postfire assessment was collected and put into ARC/INFO files day by day as the fires spread. We intend to be better prepared to meet the needs of suppression teams in the future based on what we learned this year.

We found that people who were brought in for temporary assignment to support our GIS operation were critical in the transfer of knowledge and skills. Many people from the Pacific northwest are knowledgeable in the skills we needed and they taught our staff how to do many things in GIS. We used their knowledge in a realtime emergency situation to improve our own skills.

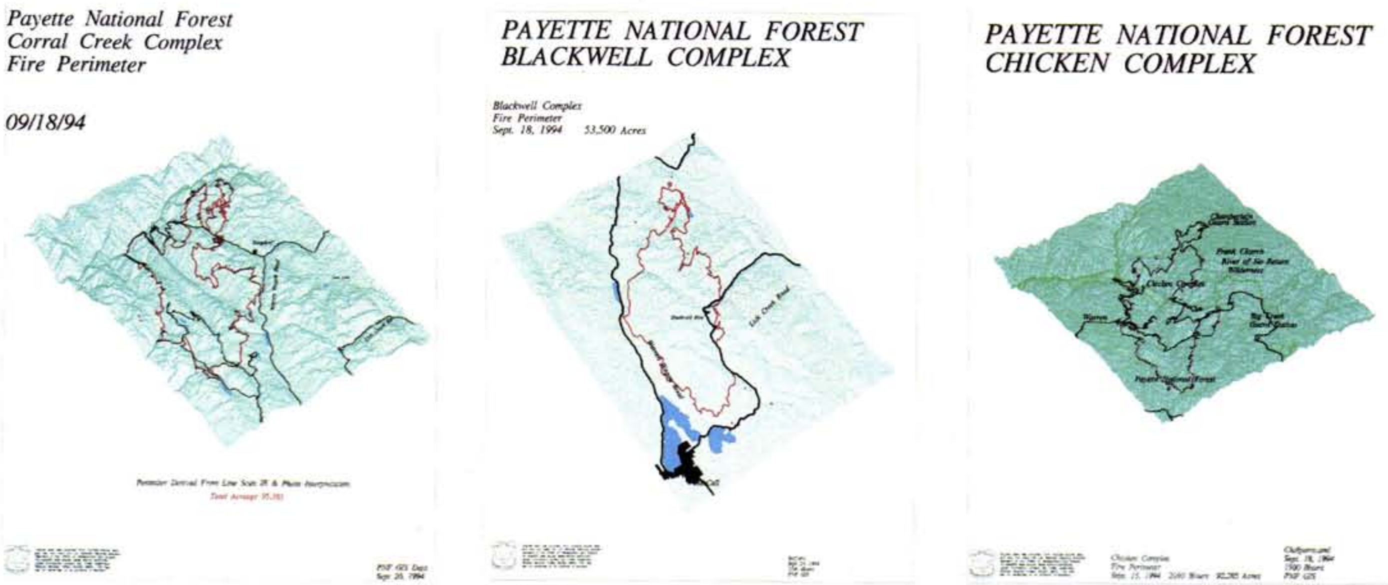
We discovered that when suppression teams found utility in GIS products, they wanted more. Most of our attempts to help with tactical planning or record keeping were accepted and we anticipate that in the future, suppression teams will need even more routine support from GIS experts.

The creation of GIS documents and products was not a one sided affair. Fire suppression teams and decision makers worked closely with knowledgeable GIS staff to describe and develop products. It was a team effort and reflected the principle that GIS is only a tool best used by resource specialists to analyze options and to choose alternatives.

we intend to be better prepared... based on what we learned this year

GIS products were of great value in public meetings. While this is not a new finding to GIS users, it was of interest to us that the public would relate so easily to illustrations of fire behavior. The products generated interest and appeared to generate confidence that we were using the latest technology in an effort to control fires in the most effective and efficient ways. The historical data we have collected will continue to be used for public involvement as we continue to work in post-fire assessments and ecosystem management.

Of critical importance was the discovery by some suppression teams that GIS could be used for tactical planning. Still, the efforts made were basic and rudimentary, but the ability to combine data sets such as vegetation inventories, slope, aspect, and elevation, road and drainage systems proved to be of help to some tactical planners. In the future, forest fuel models (reflecting what there is available to burn) and fire behavior models (that help predict fire spread and intensity) will give tactical planners even more options in GIS



Fire Perimeter Derived from Line Scan IR and Photo Interpretation

to plan safer and more effective control strategies.

During this fire emergency, we did not used to full advantage the more important tools of GIS. As we continue to develop our abilities in the use if GIS in fire suppression, we will do more analysis to help improve the safety and effectiveness of wildland fire fighters. The future should bring some worthy developments in these areas and perhaps, the days of red suns will not last so long.

Acknowledgments

This paper was compiled from information gathered from a multitude of people working on the fire suppression teams and from the Payette National Forest Geographic Information System team. I deeply appreciate the help and time they all gave me in the preparation of the paper.

About the Author

Jerry D. Greer is Branch Chief, Planning and Ecosystem Management, Payette National Forest, McCall, Idaho. The mention of commercial firms or products is for clarity and identification of processes or methods only and no endorsement is implied by the author or the USDA, Forest Service.