Eco-Link

Linking Social, Economic, and Ecological Issues

Temperate Forest Foundation Research & Education Since 1989

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Technology in the Forest

Technology is helping the forest products industry produce more with less: less waste, less pollution, less impact on the environment and less raw material input. Foresters are under increasing pressure to meet the public's growing needs for wood and paper as well as amenities from the forest. However, they often have to work under the yoke of negative public perceptions, which were created by images of our pioneering past, when the forests were seen as endless, and something to be conquered rather than sustained. Yet the reality of the modern forest products industry is sustainable forestry, to benefit current and future generations. More time is being spent educating the public on how far the industry has come. The frontier is gone and today's forestry must be: socially acceptable, economically feasible and ecologically sound. It also has to be politically practical and legally defensible. All this means that the industry has to be on the cutting-edge of information and technology. From computers, lasers, and satellites, to modern harvesting and processing machinery, this is a different industry. Better knowledge and better tools are adding up to make sustainable forestry a reality.

Information Technology makes it easier to collect huge amounts of accurate data not only to monitor the forest, but to more productively manage it. Knowledge is power and the use of Geographic Information Systems (GIS) gives land managers access to large amounts of data and information that was impossible to access before. Information made available through tools like photogrammetry (aerial photographs and other imagery taken from airplanes and satellites) and remote sensing, which can map large forest areas and help monitor and detect widespread trends of forest and land use. Computers are used extensively from the office to the field, for the storage, retrieval, and analysis of information required to manage the forest land and its resources. GIS can also be used to model various management scenarios to optimize silvicultural goals.

Adding to the information base is scientific research that is helping foresters understand the impact of their practices and is helping solve some of the problems faced by forests. Forest management employs knowledge from many disciplines and offers opportunities for people in such diverse fields as biology, chemistry, geology, hydrology, engineering, computer science, silviculture, and more. Forest management benefits from the progress made in these fields.

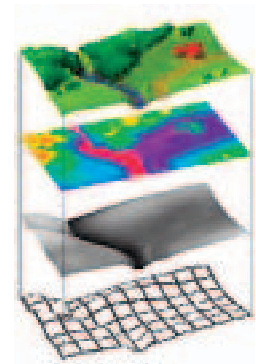
Once forest management prescriptions are dictated, high tech tools and machinery allow foresters to accomplish their goals in an efficient, economical and ecologically sound manner. Operations that were once labor intensive can be done more safely with fewer people on the ground. As an example, harvesting operations are highly mechanized and can be accomplished with as little as two machines (harvester and forwarder). Satellites and Global Positioning Systems allow forester to follow precise boundaries. Everything is computer driven. It's a different world in today's forest management.

In this Issue

Photo: Foresters still utilize traditional tools to collect data on trees—Clinometers to measure tree height, calipers and diameter tapes measure tree diameter, and increment borers measure the growth of trees.

Geographic Information Systems (GIS)

Information is the key for modern-day forest managers. For planning, writing management prescriptions, and forecasting effects of prescriptions, managers need immediate access to data and information that is accurate and meaningful. Information like stand size and geography, stand density and species composition, timber size and value; as well as spacial data such as vegetation and wildlife distribution and the locations of rivers and roads. Geographic Information Systems (GIS) provide the backbone capability for forestry and other land-based analysis. In the past, foresters had to go out into the field and collect the data by hand. This was time-consuming work and the data collected was limited. Modern GIS tools streamline data collection and integrate that data in meaningful and useful ways. Using GIS, forest managers could coax more productivity, and more profit, from forest resources with lower environmental costs.

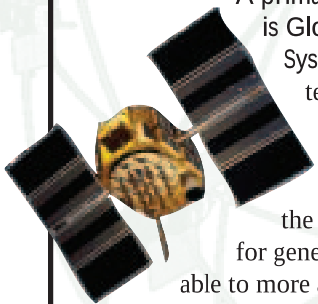


Foresters can use GIS data to help in forest management. For example, users can see on one layer how much of a particular stand is forested, the size of the trees on another layer, and the species variety on another. The selected layers can be superimposed into a graphic image for a picture of what exists at that time. *Image from GeoLas Consulting.*

What is GIS ?

A geographic information system is a computer-based tool for mapping and analyzing geographic phenomenon that exist, and events that occur on Earth. GIS technology integrates database operations such as query and statistical analysis with the unique visualization and geographic analysis benefits offered by maps and visual imagery. Map making and geographic analysis are not new, but GIS performs these tasks faster and with more sophistication than do traditional manual methods. Data is collected on the ground or through remote sensing and is added to a database. This data can be processed by computer for visualization applications such as; forest cover type and habitat classification; location of ecologically sensitive lands and endangered species; identification of land ownership boundaries; ground cover mapping and characterization (forest, wetlands, etc.); facility siting; and efficient transportation routing. Using this information, forest managers can efficiently monitor their lands and model complex processes like land capability analysis (forest health, watershed condition, and erosion susceptibility).

Global Positioning System (GPS)



A primary tool in GIS is Global Positioning System (GPS). Using technology developed by the U.S. Department of Defense, operated by the military, and adapted for general use, foresters are able to more accurately plot location data (latitude, longitude, and altitude) for use in calculating timber volume, surveying timber plots and mapping roads and features in the forest. This data, combined with photogrammes and other geographic data help foresters to accurately manage modern forests.

Using a handheld receiver, GPS takes advantage of a constellation of 24 satellites that orbit the earth as reference points to calculate position in three dimensions as well as in time. At any time, this constellation provides the user with between five and eight satellites visible from any point on the earth. GPS technology could accurately plot your position within a centimeter.

One example of a GPS receiver used by foresters to collect data

Foresters can download data gathered from handheld GPS receivers into databases and modeling programs that marry it to other GIS information that can help in planning. As the technology gets smaller, foresters will have access to portable GIS tools that help them make on-the-job decisions.

Lasers and LIDAR (Light Detection and Ranging)

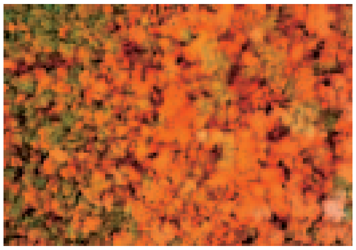
Laser technology provides a very accurate way of measuring distance and dimensions and is finding many applications in surveying and mapping applications. Laser ranging works by emitting laser pulses towards the object to be measured. These pulses are reflected by the ground and/or objects upon it such as trees and buildings. For each pulse the elapsed time between the emitted and returning signals is measured, which enables a slant distance to be computed. This technology is useful on the ground by foresters as well as for remote sensing data collection through laser altimetry.

Laser Rangefinders

Handheld lasers have simple applications for foresters, collecting measurement data within and among tree stands. Foresters can use laser rangefinders in combination with GPS technology in timber cruising, GPS offset mapping and data collection, etc. When used correctly, lasers are much more accurate than traditional methods.

Remote sensing

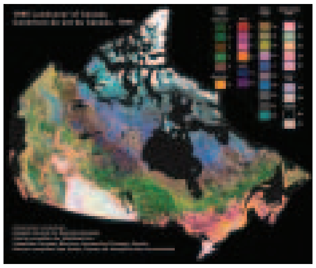
Remote sensing is a way to obtain information on forest biomass and stand conditions over large areas in a timely and cost-effective manner. The term remote sensing, sometimes known as photogrammetry, refers to measuring objects on earth without actually touching them, usually by means of some sort of photogramme. Photogramme commonly refers to photographs, but more generally means any sort of imagery. Remote sensing utilizes aerial photographs, satellite images, laser altimetry, and radar. All optical methods, including aerial photography and satellite imagery, are essentially observations of leaf area development because that is the forest component that most strongly reflects or absorbs visible and near-infrared radiation. While total forest biomass is sometimes correlated with leaf area development, there are many situations where it is not. Laser and radar methods are able to give much more detailed images, but are generally more expensive and aren't as extensive yet. In any case, used in conjunction with GIS data these photogrammes can be powerful visualization tools for foresters working out in the field and at the computer.



Aerial Color Infra-Red Image of Florida Mixed Hardwood stand. *Photo: Florida Gap Project, USGS/BRD http://www.wec.ufl.edu/coop/gap/*

Satellite image of the Pentagon, Washington, DC., *from Space Imaging, http://www.spaceimaging.com*

Topographic Map generated from laser altimetry data. *Image from GeoLas Consulting*



Land Cover of Canada map produced by Canada Centre for Remote Sensing and Canadian Forest Service from radar images.

Aerial photography

Aerial photography, photos of land-based objects taken from aircraft, has been used for at least 50 years. In the past, it has been mainly used for classifying forests by type or to distinguish between forested and non-forested land. When older images are available, aerial photographs can provide an historical perspective of features. Images can be obtained in stereo to allow fuller interpretation, and modern images can be obtained at different wave lengths and analyzed electronically, Aerial photography is mainly suitable for local to regional-scale analyses.

Visible and near-infrared satellite imagery

Satellite images have been available for about 20 years. Images, such as Landsat, are obtained frequently and their coverage is global. Satellite information is most useful for broad-scale assessment of the presence or absence of certain vegetation types, such as for an assessment of land clearance rates.

Data is usually presented as the Normalized Difference Vegetation Index (NDVI), which is essentially a measure of projected leaf surface area. Images are available at different resolutions. Older images with coarser resolution are generally cheaper or available free of charge, whereas newer images with finer resolution are often more costly. The primary source of medium resolution satellite imagery is the country of India. Through its distributor they are the sole source for US and Canada imagery from their two satellites.

Laser altimetry

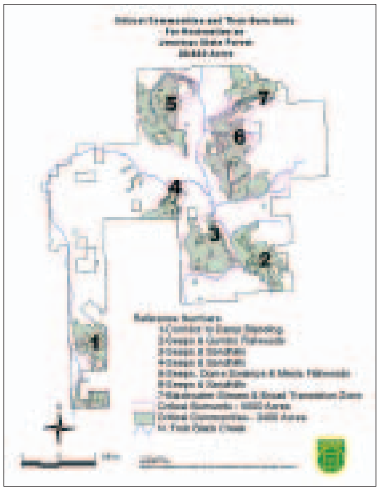
Laser altimetry is a method that allows very accurate calculations of biomass. In laser altimetry, a light pulse is sent from an aircraft to the ground. By measuring the time it takes for the light pulse to be returned to the instrument it is possible to calculate the distance from the aircraft to the ground. Some light is reflected from the canopy and some passes through the canopy and is reflected back from the ground. This provides precise information of a region's ground elevation and average canopy height. Standing biomass can then be computed from correlations between canopy height and tree biomass. Combined with GPS data, laser altimetry can provide useful 3D mapping of ecosystems.

Synthetic aperture radar (SAR)

Anyone who has watched the weather reports on the television news is probably familiar with radar images. Like laser altimetry, radar sensors emit their own electromagnetic radiation and record and deduce information from the backscattered signal. SAR can produce high resolution imagery without the atmospheric limitations of optical methods and can be mounted on satellites.

Monitoring and Modeling

GIS applications enable managers to look at the "big picture" and simulate resource change over time under various conditions. Computer applications, in the context of natural resources, fall into two categories: monitoring and modeling. Monitoring systems study and track industrial and natural processes while modeling programs are used to simulate processes and test theories.



GIS Map generated to monitor fire restoration on a state forest.
Courtesy of Florida Department of Forestry.

Monitoring and modeling programs contribute to an integrated toolbox for foresters managing resources. Monitoring programs utilize raw data collected by various methods and put them into a dynamic context. Foresters use monitoring data to establish a baseline to compare the results of forest management activities and determine whether or not they were successful. Managers can see the economic impact of the harvest and the impact on nearby wildlife. Even if foresters did not use a modeling program, they could still make informed assessments and decisions about the forest with monitoring data.

Building on the data from monitoring programs, computer models programmed to simulate real-world processes can help visualize expected outcomes of management activity. For example, when combined with data such as species composition and merchantable volume, it is possible to analyze the effect a road network design has on delivered wood costs. Other GIS applications of road and forest access planning include: terrain and slope stability analysis, cut and fill estimates, visibility and view-shed analysis, alignment and grade calculations, right-of-way corridor studies, and dynamic comparison of access and haul cost attributes for several road access alternatives. The success of modeling programs relies on the accuracy of the data generated from monitoring programs. Visualization technology is also being used to enable decision makers and stake-holders to preview changing landscape patterns over both space and time.

Biotechnology

Biotechnology is an important component in helping the forest industry increase productivity of modern forests. Forest sustainability depends on global interdisciplinary cooperation in silvicultural techniques and continued research to meet projected needs while maintaining a healthy ecosystem. As less public forest land is available for commercial use, it becomes increasingly important to coax maximum productivity from existing commercial forests.

Biotechnology aids the forest industry in numerous areas. Application of enzyme technology in pulp and paper manufacture has demonstrated environmental advantages. Tree genetics offers the possibility to resolve the increased demands on forest resources through the development of trees more tolerant to diseases, pests, and chemicals, which have a detrimental impact on forest health. Phytoremediation technology has the potential to provide a cost-effective solution to contaminated soil. Results from this research will help establish plantation forests with higher productivity, more uniform wood, and more desirable wood fiber quality traits. Improved wood production would reduce energy consumption as well as costs of harvesting and transportation, which account for about half of wood costs to the mill. Greater uniformity in wood and fiber quality would provide additional energy savings in processing.

There is some concern about the consequences of using genetically modified trees for commercial purposes. The primary concern is that genetically modified trees could cross-breed into the wild ecosystem and affect it in unpredictable ways. Biotechnology, as applied to forest trees, is still a new science that requires answers to the numerous questions it continuously unveils.

> One successful example of biotechnology is in Idaho where a disease called Blister Rust was threatening the White Pine tree population.
>
> The white pines were a significant part of the biodiversity in Idaho forests and were valued for their natural resistance to frost and root rot. Since 1923 when Blister Rust was first identified in Idaho, over 90% of the white pine population has fallen victim to it. But thanks to successful breeding programs, foresters are now able to repopulate the white pines stands with Blister Rust resistant white pine trees.

The American Forest and Paper Association, through Agenda 2020, and the National Research Council of the National Academy of Sciences, through its work Forestry Research a Mandate for Change, have recognized the potential of biotechnology through establishing common research priorities for the industry.

Forest Engineering

Advances in technology over the last century have allowed harvesting and processing techniques to evolve at a lightning fast pace to help keep up with demand for forest products while complying with economic and ecological demands. In the U.S., national timber harvest is approximately 16 billion cubic feet which goes to provide the public with lumber, wood products, paper and pulp products, and wood by-products. In 2000, for example, over 90 percent of single-family homes built in this country (approximately 1.6 million—each using 13,127 board-feet of framing lumber) were constructed with wood framing. In addition, Americans also used an average of 718 pounds of paper per person. As increasing amounts of federal timber are put off-limits, industrial and private forests must be managed more intensively. Foresters must be concerned with the long-term health of the forest and be able to execute management practices that adhere to environmental policy and social goals along with the economic. In order to stay competitive, the industry must do more with less, increasing the yield from forestland and individual trees.

> The forest products industry owns about 13 percent (67 million acres) of the nation's forestland and from that, produces almost 30 percent of the nation's annual timber harvest.
>
> In 1996, our nation's timberlands achieved a net annual growth of more than 23.5 billion cubic feet of timber. When compared to an annual timber harvest of approximately 16.0 billion cubic feet, net growth is surpassing harvest by 47 percent.
>
> Statistics from AF&PA, U.S. Forest Facts and Figures 2001

The business of harvesting and processing trees was traditionally very labor intensive, dangerous, and often destructive to the sites. Processing logs required much manual labor which resulted in many injuries and very high workers compensation insurance costs. Road building and some harvesting techniques degraded the environment and caused damage to residual trees. Numerous roads were built to access harvesting sites which contributed to erosion and watershed and habitat degradation. Deep ruts can be left in the spur roads and skid trails resulting in root damage to remaining trees. Past practices often resulted in much timber waste and unnecessary labor costs. The need to address these issues and to achieve higher productivity resulted in an explosion of high tech mechanized machinery to harvest and process trees in the forest.

Forestry today looks nothing like that of a century ago. Forest owners and foresters have access to a wealth more silvicultural information which allows them to write forest management plans that plan for the long-term economic, social, and environmental needs of the stand. And there are many tools available to help carry out those plans in the same spirit without the downsides that existed in the past. Most harvesting operations are now mechanized, requiring the operator to have a higher degree of training and competency but providing a better degree of comfort, safety, and productivity. Modern equipment is now able to harvest and process trees to log lengths in one motion, saving processing time in the mills and helping keep organic matter on-site. Computer systems are integrated into harvesting systems, allowing optimization of the harvest. The machines themselves are purpose-built and designed to be more versatile and to have lower impact on the site. In all areas of forest engineering; road building, harvesting and processing, and transportation; technology has helped advance the industry far beyond the common image of Paul Bunyan. Technology is the key to safety, productivity, reduced costs, and environmentally sensitive techniques.

Temperate Forest Foundation Teachers' Tour participants observe harvesting systems up close.

A tracked harvester demonstrates its agility in sloped conditions. Its multipurpose harvesting head can cut, top, delimb, buck, and stack a tree all in one motion.

A feller-buncher is able to do harvesting work quickly and more productively while keeping the operator protected.

Mechanical delimbers delimb, top and buck tree into log lengths.

A hydraulic log loader equipped with a cab riser, special log boom, and grapple.

Harvesting and Processing

Efficiency and productivity are the key themes for companies trying to meet consumer demand for forest products. Mechanized timber harvesting and processing cycles have been accelerated due to the need for more productivity and profitability, the cost of workers compensation insurance, and the trend to shorter harvest rotations and thus to smaller trees. The advent of engineered wood products has further accelerated this trend because smaller and lower quality trees can be used. In addition, environmental impact is much more of a consideration dictated in large part by legislation. Advances in harvesting and processing technology are helping achieve the many social and economic objectives of the industry. There is an equipment system for most types of harvesting, systems that are designed to accommodate: different harvesting and silvicultural methods, varying terrain and geographic features, seasonal weather conditions, smaller crews, and other considerations, all the while, practicing environmentally friendly stewardship. The main drawbacks of these high-tech systems is high capital investments on the equipment itself and increased training required for workers. While they may not be ideal for all harvesting needs they offer a high-tech solution towards sustainable forestry.

Tree Length Systems

Wheeled grapple-skidder and feller-buncher working in tandem

Modern harvesting systems completely mechanize the felling operation getting the labor off the ground and minimizing impact to the site. Machines like feller-bunchers fell and bunch trees mechanically using a boom-mounted head equipped with high-speed or high-torque saws combined with accumulator arms. The feller-bunchers are able to saw the tree as the accumulator arms clasp the tree in its head, holding it while other trees are gathered until they can be piled. Once piled, a grapple skidder equipped with a loading arm can collect the piles and take them to the landing to be delimbed, topped, and bucked into log lengths by a stroke delimber. Finally a hydraulic log loader sorts and loads the logs onto a truck.

Harvesting systems offer many advantages; speed, better wood utilization due to low stumps, lower production costs, and dramatic safety increases for workers who work off the ground in the safety of a cab. The tree-length method is most applicable to clear cutting, but can be used in row thinning and partial cutting.

Future Innovations

The latest innovation in forestry equipment is a futuristic 'Walking Forest Machine' which allows greater access to timber on steep slopes or in soft soil while being gentle on the earth. The machine maneuvers on six, insect-like legs that allow it to move sideways and diagonally as well as forward and backwards. It can also step over obstacles like stumps and exposed roots making it less impacting on roots, understory plants and soil.

Cut to Length Systems (CTL)

Cut-to-length systems have proven ecological and economic advantages in small timber tracts and in stands where uneven-aged harvesting methods are used. Cut-to-length systems were developed in Scandinavia, where harvest technology was pushed at the same rate as the ecological and silvicultural knowledge base. CTL mainly consists of a harvester and forwarder.

Harvester using its processor head to prepare logs.

A harvester is a machine that can process trees in one motion with a sophisticated processor head. The harvester's head can grasp a tree near the base and cuts it off near the ground. While the tree is still in the grip of the processor, it is delimbed, topped, and bucked into log lengths using an on-board computer that measures the tree and computes optimized cut lengths.

Forwarder loading cut logs for transport

From here the other part of the CTL system, a grapple-equipped forwarder, can pick up the cut logs, load them into its payload cradle, and carry them out off the ground instead of dragging them from the site.

Cut-to-length systems have several advantages. Harvesters process the trees in the woods, leaving the tops and limbs on the forest floor where the nutrients can return to the soil. This organic material also protects the soil from compaction and rutting as the machines drive over it. Instead of skidding or dragging "turns" of logs, the self-loading forwarders carry the logs piggy-back style to the road where they load them onto trucks. This helps alleviate erosion and soil loss to the site. The need for large landings is eliminated, along with the problem of what to do with the debris (slash) which was the result of processing at the landing.

Transportation

Technology is also helping overcome the impacts of transporting logs from stump to mill. Yarding and road building are necessary parts of the harvesting process which can have serious impact on the site and surrounding stands. Traditionally, cut trees were skidded from where they were felled in the forest to a landing where they were processed. Skidding pull logs along the ground, and, as they are moved through the forest, the dragged logs cut channels into the earth; helping erode the soil, damage roots, and tear bark off the trees that are left standing. In selective harvesting methods, the use of skidders can damage and even kill many of the trees that are purposefully left standing. That can drastically reduce the future value of the remaining trees, both biologically and economically. Roads improve access to the sites and allow logs to be transported from the landing to them mill but can affect hydrological cycles and erosion if not properly executed. Newer transportation technology helps ease the impact of removing trees while helping maintain costs and the integrity of the site.

Yarding

Research shows that traditional log skidding causes more erosion and soil loss when compared to the systems that transport the logs off the ground. There are many options available to extract timber from the harvesting site. These choices must be matched to the timber, terrain, and underfoot conditions. Depending on the conditions and economics the forest engineer can choose the appropriate mix of ground, cable, or aerial systems in order to minimize the impact on the harvesting site.

Forwarders and grapple skidders offer solutions by carrying their loads off the ground on tracks or wheels and require less trips to carry out the same amount of timber as traditional skidders.

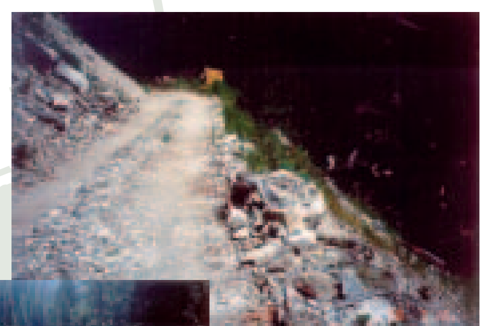
Helicopter Logging: helicopters are used in steep and remote locations

On steeper terrain where access is impeded and skidding removal would subject the site to erosion, logs can be yarded by a cable systems or relayed or swung to a landing by a log loader. They can also be yarded by helicopter, an high-production option that isn't impeded by terrain, access, or harvesting method. Helicopters are expensive and can be limited by weather conditions, but in steep or sensitive areas they are often the best option.

Road Building

In the past, road building didn't take environmental impact into account. In the early 1930s, the U.S. began a program of aggressive road-building in forest areas. Today the National Forest Road System consists of more than 380,000 miles of roads. These forest roads are used to: manage the forest; harvest timber; fight fires, insects, and disease; salvage dead and dying timber; and to access forest recreation. Most forest roads were built with the economic incentive of timber harvest. But this road building was responsible for many of the past problems associated with harvesting such as erosion and stream sedimentations. Slope and road failures are highly visible, cause stream degradation, and create negative public perceptions.

Today, roads are being built to very strict standards in compliance with forest practice acts. In many areas, road construction has been minimized by using forwarders, skyline cable harvesting systems, and helicopters to transport the timber over longer distances, and over steep and sensitive terrain. Managers can utilize computers and GIS data to model and plan optimal road placement. Planning minimizes land loss to roads and skid trials as well as overall ground disturbance. In addition, old, unnecessary roads are being decommissioned and restored to natural states.



An old logging road is returned to a natural state in a road decommissioning project in Idaho
Photos: USDA Forest Service, Clearwater District

Glossary of Terms

Feller-Buncher
A machine that fells trees using a circular saw. The machine can cut large trees in rugged terrain or may cut and accumulate several smaller trees to create a perfect sized bunch for a grapple skidder

Ecosystem
A natural system, which functions as a unit. An assemblage of living organisms, reacting to each other and their and their non-living environment.

Commercial Forest Land
Forestland that is capable of growing 20 cubic feet of wood or more per year is considered "commercial" forestland.

Forestry
The art and science of managing a forest (Forestry Tools, *Forest Focus*, Winter 2001)

Forwarder
A machine that works in tandem with a processor to create a cut-to-length system. The forwarder uses a grapple to pick up logs from the forest floor and then "forwards" these logs to a deck for sorting or it may load them directly onto a truck.

Geographic Information System (GIS)
A computer software system (often including hardware) with which spatial information may be captured, stored, analyzed, displayed, and retrieved.

Landing
A place where logs are assembled, processed, and loaded on trucks for transport to mills.

Photogrammetry
The art and science of obtaining reliable measurements through use of photographs.

Silviculture
The art and science of growing and tending a forest (managing stands of trees to achieve desired outcomes relative to species composition and stand structure).

Single Grip Processor
A machine that is able to grab a tree, cut it, delimb it and buck it to log length all in one continuous motion.

Skid
The bunch of logs pulled behind a track or wheel skidder. Also known as a pull, turn, drag, or twitch among other names.

Skidder
A machine on tracks or wheels used to drag logs from the forest to a landing where they can be further processed and loaded on a truck. Skidders are equipped with cables or grapples.

Slash
The residue left on the ground (the limbs, bark, uprooted stumps, and small stem wood) that is not usable for commercial wood products but may be useful as biomass fuel.

Sustainability
"Meeting the needs of the present without compromising the ability of future generations to meet their own needs."

Sustainable Forestry
Forestry that fully integrates social, economic and ecological needs for the benefit of current and future generations. Forestry that maintains the diversity, productivity and resiliency of the working forest. Forestry that provides for the reoccurrence of desired future outcomes.

Sources

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http://www.fpl.fs.fed.us/documnts/pdf1999/sykes99a.pdf

Role of Forests in the Global Carbon Cycle, Miko U.F. Kirschbaum, CSRIO Forestry and Forest Products, Canberra, Australia
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Atterbury Consulting: http://www.atterbury.com

Columbia Helicopters: http://www.colheli.com/

Summary

Technology plays a huge role in modern forestry. Because of the knowledge and tools that are available because of it, we can manage and utilize our forest resources in a more sustainable manner than ever. Past forest practices have earned the industry a reputation as low-tech and archaic but this reputation doesn't apply to modern day forestry. Science and technology are being utilized in all aspects of forest management towards doing a better job maintaining the nation's forests.

More Info

The Global Positioning System The Aerospace Corporation P.O. Box 92957 Los Angeles, CA 90009-2957
http://www.aero.org/publications/GPSPRIMER/GPS-Primer.pdf

Cut-to-length, Tree Length or Full Tree Harvesting?, Dr. Reino Pulkki, R.P.F., Lakehead University, Faculty of Forestry
http://www.borealforest.org/world/innova/compare.htm

In late 1994, forest products industry leaders created Agenda 2020, a vision which establishes long-term goals and broad research priorities for the forest products industry and provides the touchstone used in guiding program activities.
http://www.agenda2020.org/

US Department of Defense GPS Standard Positioning Service Performance Standard in PDF format
http://www.navcen.uscg.gov/gps/geninfo/2001SPSPerformanceStandardFINAL.pdf

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