

## Development of Forest Engineering in China — Looking Ahead Ten Years

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### ABSTRACT

This paper highlights the development and prediction of forest engineering and forest engineering education in China. The activities of forest engineering has changed significantly since the introduction of a market economy into China. Profitability and economic efficiency are emphasized. Techniques and education systems in forest engineering must not be transferred mechanically from other countries. They must match existing social, economic, and physical conditions. The importance of forests in supplying non-wood forest products such as water and soil protection, climate adjustment, honey, nuts, mushrooms, medical plants and wildlife need to be considered when decisions are made about forest engineering activities, such as forest harvesting. Forest operations, as an important part of integrated forestry, should be planned from the point of view of sustainability of both timber and non-timber forest products. It is evident that a concerted effort is needed to encourage forest development programs that harmonize interests in conserving forests as well as to wisely use the potential of the forest while maintaining its full regeneration capacity. All forest engineering activities, such as forest resource surveying and harvesting planning, forest road planning and construction, harvesting, post-harvesting site disposal, planting and protection and so on should serve the key purpose of sustainable forestry. In view of the forest quality decline in China, it is essential that forest engineering practices are carried out in a manner to guarantee the sustainability of the forest resources base. "The Natural Forest Protection Project", just started in 1998 in China brings challenges and changes to forest engineering. The environmentally sound, low cost and high efficient techniques of forest engineering will be the spotlight of research in the future.

**Keywords:** *Forest engineering, development, 21st century, looking ahead.*

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### FOREST RESOURCES

Forests have multiple-functions. They not only provide timber as raw materials, but also protect such resources as water, soil, and the ecosystem. From an overall point of view, the protection functions of forests, especially in mountainous areas, are extremely important to humanity. Due to the extensive destruction of forests in mountainous areas, there is a risk of serious environmental consequences such as reduced water supply, decreased agriculture production, increased danger of erosion and flooding, instability of mountain hillsides and adverse impact on climate conditions. The 1998 disastrous extensive flooding in north and south China, during which thousands of people were killed and millions of homes and agricultural fields were destroyed, was partly caused by the consequences of overharvesting of mountainous forest in the upstream areas of Songhua and Yangzhi Rivers. Effective protection of the mountainous forests has become a problem of national significance.

According to the latest survey of forest resources in China from 1989 to 1993, the total forest area is 133.7 million hectares, 0.11 hectares in capitacion, of which the plantation forest is about 33.8 million hectares. The forest stock has been increased to 11.785 billion cubic meters, 9.89 cubic meters per person, with an increasing rate of 70.6 million cubic meters per year. Forest coverage proportional to the whole land area is up to 13.92% now, increasing 0.2% each year. There are more than 30,000 species of plants and 100,000 wildlife species in the forest ecosystem in China. With the increase of forest quantity, the quality of forest resources has been decreasing rapidly. Most of the natural forests have been cut, and the plantation forest is too young to be harvested. The rest of the forests are scattered in the outlying inland regions unsuitable for agricultural purposes. In addition, the total decertification area is reaching 1,530,000 square kilometers, 15.94% of the total land area of China, with an expanding rate of 2,000 square kilometers per year. On the other hand, the population in China is growing steadily every year. A great deal of land, covered by forest 30 years ago, is now occupied by people. During this period the population in forest areas increased more rapidly, about twice that in the other kinds of rural areas, such as agricultural and prairie. Most of the people in the forest area are living on forest resources, particularly on the timber. They cut down the big size trees for their food and fuel wood as well as for their other consumption purposes. Under constant attack from people, including harvest-

ing and other adverse impacts, the different forest ecosystems are getting smaller and weaker, and some have even disappeared.

The Chinese government has started "The Natural Forest Protection Project" in September of 1998, which means there will be no timber production in natural forests in the coming few years. The project is really a challenge, but also a chance for Forest Engineering in China in the near future. Timber production at the national level would be decreased rapidly year by year.

## **FOREST INDUSTRIES**

The forest industries in China are composed of timber production industry (e.g., forest harvesting, timber processing), wood-based panel production industry (e.g., particle board, fiber board and plywood) and forest chemical product industry (paper, rosin) as well as furniture manufacturing, of which the timber production industry dominates nearly 71% of the gross net production value of forest industries. The wood-based panel industry is ranked second, according to the economic criterion, about 16% of the total value. The furniture production and forest chemical product production are ranked third and fourth, 7% and 6% of the total value respectively. Forest harvesting is a high proportion, about 61.4%, of the gross net value of forest industry production according to the statistics in 1994. This proportion is obviously quite high and should decrease significantly in the future.

## **FOREST ENGINEERING**

In the 1950s and 1960s, the economy in China was a socialist planned system which placed a rigid policy on forestry. All forestry enterprises were state-owned, carrying out their forestry activities according to the plan approved by government. All forest products of these enterprises were distributed to users by government. The government paid salary and wages to forestry workers. The forestry enterprises did not take care of their own costs and profits.

The general policy of the forest industry in China in the 1950's was "Take example from Soviet Union in all fields". In forest operations, almost everything was introduced from Soviet Union, including cutting systems, harvesting systems and logging ma-

chinery. The clearcutting system took the place of selection cutting, regardless of the physical conditions. The Russian crawler skidder KT-12 was introduced to replace animals and labor in extraction of timber. The tree-length system replaced the shortwood system in Northeastern China. The chainsaw "Drujba" was introduced in 1958. All log handling equipment and devices were developed according to the examples from Soviet Union.

Only after decades of extensive clearcutting, did Chinese foresters find that the forest resources decreased rapidly and natural regeneration in many regions was not reliable. People have gradually recognized the fact that there are definitely great differences between China and Russia. Russia is very rich in forest resources while China has a very limited forests. The social-economic conditions are quite different in these two countries. After 1980, when the market economy system was introduced into China, it was understood that technology should not be transferred mechanically from industrialized countries into developing countries. The development of technology must take full advantages of resources which are in abundance and, therefore, comparatively cheap.

## **Cutting System**

Clearcutting without area limitation prevailed in 1950's in northeastern China, causing serious problems for the environment and regeneration. Many research works were concentrated on the impact of various cutting systems on the environment and regeneration. Since 1970s, clearcutting was replaced in many regions by selective cutting. Clearcutting is now permitted with limited area restriction—no more than 5 hectares, followed by manual regeneration-planting. Experiments show that selective cutting, in spite of the more expensive logging cost, if carried out properly, may result in optimum protection of the environment and regeneration. Since the 1970s, selective cutting has been the dominant cutting system in most areas of China. In protection forests on steep slopes and environmental sensitive mountainous regions, it is the only permissible cutting system.

With the development of forest plantations and the execution of Natural Forest Protection Project at the national level, the thinning system and selective cutting system will be the prevailing cutting systems in China in the coming 10 years.

## Equipment and Technology

Like many other developing countries, China is characterized by: (1) the ample availability of cheap labor; (2) the expensive machinery cost; (3) lack of funds for forestry activities and road building; (4) shortage of energy; (5) lack of maintenance and repair facilities for advanced machinery.

These characteristics determine that the forest harvesting technology in China should match its existing social-economic and physical conditions, but not the same as in the industrialized countries for the time being. However, before 1970, when the economy in China was planned, technology in forest operations, as well as in most other industries, was just the same as in the Soviet Union. The high-handle chainsaw, crawler skidder, cable block loading device, bridge crane for log piling and loading at log yard, conveyor for log sorting, etc. were quite popular in northeast of China. A significant part of research work was carried out on design and development of advanced equipment, while the production cost and profit were neglected. Even in late 1970s, a limited number of modern advanced logging machinery (feller-buncher, processor, harvester, etc.) was introduced from Finland, USA and Austria. The results indicate that these complicated machines are not cost-effective for China. For example, the mobile yarder Steyer costs 20 times higher than the domestic semi-stationary winch, while its production is just 2-3 times higher than that of the latter.

Only after the market economy system had been introduced into China did the Chinese get wiser. The term "appropriate technology" was first used in forestry of China in 1981. Some scientists made recommendations for application of appropriate, not advanced technology, in forest operations. Cost-effective, labor-intensive technologies become more attractive. Animal and manual logging have come

back to the forest again. The study and development of more sophisticated equipment stopped. The simple mechanized and cost-effective technology now prevails in China. From 1980s to 1990s, the tree length and shortwood systems are dominant in the Northeast while the shortwood system has been the traditional harvesting system in the South, both in manual logging and cable yarding.

A great deal of research work has been concentrated on improvement or development of logging equipment. Before 1970, the only logging machinery used in the woods were chainsaw-051 and crawler skidder J-50, which had been introduced in 1959 and 1964 respectively.

The chainsaw-051 is distinguished by its high offset handle bar which serves as a fuel tank at the same time. This configuration enables the operator to fell trees without bending down, thus reducing fatigue significantly. The wire rope recoil starter can be removed and stored in a pocket after use. The chainsaw is powered by a two-cycle three-horsepower gasoline engine and is hand oiled. The length of saw bar is fixed at 44 cm. The saw bar can be rotated 360 degrees each way, so it can be easily changed from felling position (horizontal) to bucking (vertical) or vice versa without rotating the whole saw body. It weighs 11.5 Kg, which is too heavy to handle for an operator. The noise and vibration level (110 decibel and 25 g) of 051 is much higher than that allowed by ISO. Research work has been mainly directed to decrease the weight, noise and vibration. In the 1970s, new models, GJ-85, YJ4 and CY5, were introduced. The old model 051 had also been improved. Now, the 051 is still a popular chainsaw in Northeast China, while YJ4, CY5 with a short handle are common in Southern China. The major specifications of this chainsaws are shown in Table 1. In spite of the advantages the new models have, the old 051 is still very popular with loggers, especially in Northeast China.

Table 1. Chinese chainsaws.

Tech. parameters	Models			
	051	GJ-85	YJ4	CY5
Mass (Kg)	11.5	12	9.5	6
Eng. Displac.(cm <sup>3</sup> )	94	85	78	50
Power/Speed(Kw/rpm)	2.2/5000	3.7/7000	2.9/6000	1.8/7500
Chain Specif.(mm)	15	10.26	10.26	9.4
Guide Bar Length(mm)	440	440	470	300

The crawler skidder J-50, powered by a 50 Hp diesel engine through a five speed transmission, equipped with a single drum winch and frame bank on the rear, which can be raised and lowered hydraulically to carry the front end of tree-length off the ground, is specially designed for operations in forest terrain. The flexible carrier can automatically adjust to terrain conditions and travel in the woods more smoothly than agricultural tractors. It has a downhill skidding capacity of 5-8 cubic meters. The cabin is very poor, and the operators suffer severe cold and heat in the winter and summer respectively. There is no protective structure, such as ROPS (roll-over protective structure), FOPS (falling objective protective structure) and OPS (operator protective structure).

A four-wheel drive skidder J-80 was introduced at the beginning of 1980 with an expectation to replace J-50. Equipped with an 80-Hp diesel engine and 10 speed transmission, as well as frame bank and one drum winch on the rear, this articulated machine travels much faster than the crawler. Up to now, however, it has a limited application. It is used only for long distance skidding or secondary off-road transport on modulated terrain (less than 30%), while the crawler works on more steep terrain. The J-50 is still the most popular skidder used in China.

As the forest resources located on gentle terrain has been harvested, cutting has moved to steep slopes (more than 50%) where the remaining stands grow. The cable systems are getting more application in steep mountainous areas. All yarders used in China are semi-stationary, mounted on sledge legs and powered by engine ranging from 25 to 70

Hp. The most popular yarding system is a gravity skyline system, composed of double (or single) drum winch, skyline, mainline, haulback line and a carriage with or without built-in stopping device. The setting up of such a system requires a survey of the skyline corridor and the selection of appropriate spar tree as well as support trees in the case of multi-span system. The winch is usually mounted at the lower end of skyline where the landing is located. The main specification of cable systems are shown in Table 2. The cable systems are mainly used in Southern China.

For landing operations the simpler spar-cable systems are still widely used for piling and loading. A set of blocks is hung at the top of the two gin poles supported in an inclined position by guylines. Cable from the winch goes through the blocks to the logs to be loaded at landing, effecting cross-hauling loading along an inclined wooden frame. The other loading device is a simple cable crane with a wire-operated overhead cable strung between two wooden spars across the road. A carriage rides on it and lifts logs onto a truck. These loading devices are mainly used in Northeastern China.

The first Chinese front-end log loader was built in 1976. Now, there are seven models of such loaders with capacity ranging from 1.5 to 7 tons. The models are ZLM-15, ZLM-30, ZLM-40, WA300-1, ZLM-50, ZLM-60 and WA470-1 (Table 3). Most of them have switching working devices (universal grab, grapple, bucket, blade). At landing, the loaders can perform loading, timber piling, grading and clearing of landings. The front-end loaders are popular in Southern China.

Table 2. Cable systems used in China.

Type of system no. of lines carriage	standing skyline		live skyline			
			two lines			
	semi-automatic		radio-controlled		simple	
Model	K2	MS4	JS3	YP2.5	K1	K2
Hauling direc.	1-way	1-way	2-way	2-way	1-way	2-way
Yarding dist.(km)	0.8-1.2	0.8-1.2	>1	1.5	0.3-0.8	0.3-0.8
Lateral yarding dist.(km)	0.05-0.07	<0.06	<0.06	<0.06	<0.04	<0.04
Payload(ton)	3	4	3	2.5	3.2	3.2
Productivity (m <sup>3</sup> /shift)	40	40	40	50	40	40

Table 3. Timber Loaders used in China.

Model	ZLM-50	ZLM-40	ZLM-30	ZLM-15
Mass, Kg	15300	12450	9700	5800
Model of Engine Kw/rpm	151/2100	115/2300	74/2200	40/2200
Lift Capacity, Kg	5000	4000	3000	1500
Turning Angle, Deg.	37.5	40	35	36
Dimension, cm	750x280x326	714x257x334	634x255x310	523x190x280
Min. diameter of fork	400	850	400	160

As the cutting system will be changed from clearcutting into thinning and selective cutting, the equipment used for forest harvesting will also be changed respectively. Chainsaw will remain as the dominant felling equipment. Light weight machines for timber extraction (skidder, yarder, forwarder) technology will dominate in the next ten years. Short wood or cut-to-length systems will replace the existing tree-length system, which brings damage to the residual stands.

### Harvest Planning and Road Network

The traditional layout of forest roads in China is to build roads along the stream valley. There are no roads at mid-slope or ridge. Most roads are located along stream valleys under mountainous conditions. The shape of timber harvesting settings are often irregular depending upon topographic features and area limitation, with upper boundary at hill ridge and lower boundary at road side along streams. So the skidding distance directly depends on slope length which often exceeds 2000-3000 meters.

As the forests close to the roads are harvested, logging sites are moving further from roads where forests are left unharvested. The landing remains at road sides, so the skidding distance is getting bigger and bigger, sometimes over 2-3 kilometers. Most forests to be harvested in China are growing in mountainous areas. To solve the skidding distance problem, some loggers locate the landing near the stump area and implement various means to connect the landings with the roads at the valley: cable-railway, cable way, rubber-tired skidder, etc.

The theory of optimal road spacing (Matthews) was introduced into China in 1970s. Studies were made to determine the optimal road spacing in forest regions. However, due to lack of funds and difficult terrain, the density of road network is very low, about 4-6 meters per hectare. Even in the most developed forest region—Northeast, the density of

road network is just 5-7 m/ha.

Forest harvesting in China will decrease significantly in the near future. Forest cutting of the natural forest in the upstream area of Yangzhi River has been prohibited completely since 1998. Most forestry workers will be transferred from loggers into tree-planters-silviculturists. The road network in forest regions will mainly meet the silvicultural requirement. So, the density of forest road network will not increase greatly in the next ten years.

### Computer Application

Computer application in forest engineering will find application in the near future. The advanced sophisticated machines, such as harvester, feller-buncher, delimeter, processor, etc., cannot become the prevailing technique due to their high cost and adverse impact on the environment. The earliest computers were the PC1500, Apple II and IBM-PC. Now, the X86 compatible and Pentium II microcomputers are the dominant systems. The different versions of Windows, MS-DOS operation system and general programming languages such as BASIC, FORTRAN, Foxbase, Foxpro, C and Visual Basic are widely in use.

Forest operations involve the forest resources, environment, man and machines. It is necessary to handle information in all related areas, which requires an overall resources information system. The computer can help us to evaluate different management plans and determine the best one. Computer Aided Design (CAD) has been used in logging operation planning, cable yarding design, optimum bucking, civil engineering design and other fields. With the development of optimization techniques, some optimum design systems have been implemented. By applying network analysis and linear programming, a logging network analysis system can evaluate the maximum flow, shortest path, least-cost flow and the critical path. The technique can be

used for harvesting planning, layout of road network and tree-length bucking.

The GIS (Geographic Information System) has been used in the northeast forest area of China in planning forest road networks with economic and environmental considerations.

Computers have been applied mainly in survey and planning of forest resources, management of timber production, logging survey and design, cable system design, timber harvesting planning, transportation and automatic control in wood processing as well as forest engineering education. With rapid progress in computer techniques and increasing demand for intensive forestry, computer applications will spread further to the field of information management of forest resources, decision making support, optimum design of logging, and geographic information systems. 3S (RS, GPS and GIS) techniques will also play quite important roles in the applications mentioned above.

### **Environment Protection**

Environment represents the essential conditions for human living, ecological balance and sustainable forestry. Environment protection has become the worldwide concern. A series of research work has been carried out on the impact of forest operations on sensitive sites and regeneration.

The Ministry of Forestry, People's Republic of China, issued the management measures for forest harvesting and regeneration in 1987 which involves three methods of slash disposal: slash piling, spreading of slash over the site and slash burning. The impact of different methods of slash disposal on soil and water loss has been studied. The spreading of slash over the site (no treatment) has the least adverse impact on soil, water and nutrient loss among the three methods in Jilin Province.

Among the methods of timber extraction in the forest, animal skidding is one of the appropriate measures with low impact on the forest environment, and a moderate cost. It fits the poor operation conditions of forest harvesting, particularly in the forest with low density. The improved animal skidding techniques will definitely play an important role in the thinning operations of plantations in the coming ten years.

Forestry machines, especially skidders, cause definite compaction of soil by increasing the soil bulk density, decreasing the aeration porosity and the

saturated hydraulic conductivity of the soil, which has the adverse impact on growth of seedlings and forest regeneration. Studies show that rubber-tired machines have more significant impact on soil physical properties than crawler machines. Selecting dry or frozen soil season for forest operations and increasing the contact area between the machines and soil are helpful to reduce the soil compaction. Studies on site impact caused by forest operations, methods and techniques for site protection, improvement and amelioration are getting more attention in China. Environmental protection will be the focus of attention which both foresters and forest engineers will always concern themselves with in forestry activities.

## **FOREST ENGINEERING EDUCATION**

Forest engineering education in China consists of three parts: high education (bachelor, master and doctor degrees), professional education and continuous education (adult training).

### **High Education of Forest Engineering**

There are 10 forestry universities or colleges and 20 agricultural universities or colleges which have forestry departments in China, of which Northeast Forestry University (NEFU) is the largest one. About 6,000 students and 2,200 staff are with NEFU. The undergraduate program in forest engineering is distributed in 8 forest universities or colleges, of which forest engineering at NEFU, both undergraduate and graduate, is at the leading position in China.

According to the survey in 1995, the amounts of undergraduate and graduate students at forestry universities or colleges, distributed among more than 40 majors, are 33,984 and 819 respectively. For graduates, 227 students are doctoral degree candidates and 592 are master degree candidates. Forest engineering is one of the majors in a reformed program. 8 PhD students (3 year program), 30 master (3 year program) students and 762 undergraduate (4 year program) students were involved in this program in 1995. At present, the graduates who work in the forest engineering field or the fields close to forest engineering are 80%, 50% and 20% for the PhD students, master students and undergraduate students respectively. The rest part of graduates are involved in government, manufacturing and communication enterprises, overseas trade companies, finance companies and institutions related with education.

The Education Ministry of China carried out a project, to cut 576 majors in the universities or colleges to 249 at the national level. In June of 1998, this project was accomplished. Forest engineering is one of the 249 majors. A project of education reform in forest engineering, towards the 21th century, has started since 1996 and will last until 2000. The main contents of this project are: (1) to change original objectives from more specific to more general; (2) to reform the curriculum system, aiming at promoting proportion of basis course, training of operational ability, humanity and selective courses; (3) to reform the individual courses aiming at promoting the high technology and compressing the content of textbook work in order to enlarge the information flow rate.

The higher education in forest engineering in China will be increased smoothly in the coming ten years due to the increase in overseas forest exploitation. This also brings a great difficulty to forest engineering education. Another course system, the overseas exploitation knowledge, international engineering contracts and so on, will be needed. Meanwhile, the knowledge of intensive forest management and environmental considerations will be strengthened. The coming model of undergraduate education of forest engineering in China will be "three-year general + half-year major courses + half-year project". The graduates would have more choices to look for jobs for themselves.

### **Professional Education of Forest Engineering**

There are 129 professional schools of forestry in China, and nearly 20% of them have the forest engineering program. According to the statistics in 1995, 9713 working staff are involved in these professional schools which have about 51,000 students. Among these forestry schools, Mudanjiang Forestry School and Yichun Forestry School have a good reputation in forest engineering program in China.

After a two year study, most of graduates from these forestry schools go to forestry enterprises or forestry sectors involved in forestry activities. The majority of the graduates of forest engineering programs, about 85% of them, are working with forestry enterprises and forestry farms. Unlike that at forestry universities, the forest engineering program at these schools mostly concentrates on the technical and operational part, rather than theoretical part. Thus most of the graduates from these schools work quite closely with practice, normally as technicians or workers. They are welcome by the forestry en-

terprises and forest farms.

### **Continuous Education of Forest Engineering**

Each forestry university or college has one forestry continuous education institution. Unlike the above two kinds of education, there is no age limitation for the students to the continuous education in forestry. Around 6720 students were studying at these institutions for their continuous education in 1996. The amount of this kind of student is growing smoothly over recent years. Most of them have the non-degree education, just between high education and professional education.

The amount of students from these kinds of professional and continuous education institutions, who were involved in forest engineering program, was significantly decreased in last ten years due to the hard working environment and "The Two Crises" (resource crisis and economy crisis) occurring in the forest area in last decade. It will gradually decrease in the coming ten years due to the reasons mentioned above, and the execution of The Natural Forest Protection Project in China. It is also one of the biggest challenges to forest engineering education in China at present and in the future.

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