Safety and Training in Harvesting

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Contents

Abstract

Safety and training in harvesting has become more and more important in the last decades. Forest work always has been considered as being extremely hazardous and causing health problems when practiced over longer periods. Today a clear trend is going toward fully mechanized harvesting systems,

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where modern and sophisticated machines have to work together to perform a smooth operation. For this purpose the management and administration of harvesting teams has to be improved, where planning, organization, staffing, directing, and controlling are applied. Management and staffing are important to create a highly productive and safe work environment, with motivated people performing as a team. Staffing is the most important management tool concerning safety and training in harvesting operations. The skills of operators moving million dollar machines have to be tested before hiring and trained adequately to reach a good performance. The instruments for motivating the employees and workers make part of efficient management. Training is one of the possibilities to improve and update the skills and this way increase working satisfaction and performance of the worker. Determination of training may be done in three steps: analysis of needs, development of action plans, and evaluation of success. It is important that the workers and operators reach a level of the learning curve where they combine high productivity with good quality and safe work. Adequate professional training also improves working safety and the health of the operators. High accident and death rate in forest work can be reduced by adequate training, but also working conditions have to be adapted to the needs of the workers. A safe working environment is a precondition for high performance and productivity of the staff. Instruction, monitoring, and supervision are instruments to guarantee a sound working environment. On the one hand technical measures can improve working safety, like chain brakes at chainsaws or safety features in harvesting machine cabins, and on the other hand organizational measures like safety training and behavior rules are also of high importance. Special attention should be paid to personal protective equipment: helmet, protection cloth, boots, or visors have to be provided to the workers and operators according to the specific activities of their job description. In tropical countries, protection against snakes, spiders, or insects should also be considered when designing the respective personal protective equipment of the forest workers involved in harvesting operations. Working safety is closely linked to the health status and physical performance of the forest worker and machine operators. Stressed or unhealthy workers lose concentration, pay less attention to their environment, and underestimate risks. In highly hazardous forest work, this may cause severe health damages or even deadly accidents. Ergonomics are a multidisciplinary field of professional research with the aim of finding the ideal balance between the worker and its activity. It has to be assured that their basic needs as food, housing, and health are fulfilled; otherwise the workers and the rest of the staff run a high risk of accidents.

Keywords

Ergonomics • Wood harvesting, working safety • Management • Staffing • Accidents • Workload

Introduction

In the last decade, labor science became more and more recognized by companies, organizations, and governments. Legislation was gradually adapted to protect employees and workers from accidents, unsafe and dangerous work, or illness. What first was considered as additional costs for the economy today is widely recognized to contribute social sustainability. Especially in dangerous areas like forestry, working safety and training contribute to more efficiency, resulting in higher productivity, lower absence from work rates, and lower overall production costs.

Efficiency and productivity of forest harvesting depend on planning, organization, execution, and controlling. The management of human resources has become very important in the recent years to cope with the production goals set by companies. Basic instruments for managing human resources are training, capacity building, working safety, and profilers selecting the right person for the right job.

In 1996 the Food and Agriculture Organization (FAO) published the FAO model code of forest harvesting practice. In chapter "► Safety and Training in Harvesting" of this guide, a group called "forest harvesting workforce" describe the importance of the components "management" and "administration" for harvesting operations, just like it is the case for any other business. Forest work in general is very labor intense. Many of the activities and operations are classified as hard or outermost hard work, where ergonomics play an important role to avoid health problems, permanent physical debility, or accidents. Forestry in the tropics is diverse, including wood production in subsistence farming, large-scale tropical forest management, and industrial plantation management. Apart from wood harvested for own demand from small farmers or communities, the operations and logistics of wood production for markets become complex, also for the human resource management. The principles for personnel structure in harvesting operations are similar to companies operating in other areas. In general the hierarchic structure includes the levels management, administration, planning, support, and operations. Personnel from business, administration and economics, engineers and the field labor like supervisors, machine operators, mechanics for maintenance, and manual workers are included in the working process. These people have to be organized to work together in an efficient, productive, and safe way. For that to happen, three factors have to be observed: organization, identification, and description of the job and duties for each person in the team, and, as one of the most important issues, that each single member of the staff is healthy and motivated. The operational manager has to guarantee that the principles and goals of the company are achieved by defining the duties of the staff members; allocating the human resources, equipment, and machines; and coordinating the working processes of the operation. The sector of administration conducts the office work of the company as well as the financial issues. The planning staff, with the organization of the labor force and resources, is related to the production goals of the company. In harvesting operations, they are also the link between the other fields of forest management, like silviculture, transport, and logistics, to assure the wood supply of the company or

the market according to the planned demand. In the execution of the harvesting operations, supervisors are in charge of monitoring the production goals established by the planning staff, supervising that legal requirements and the company rules are accomplished. The operators and workers itself are in charge of performing an efficient and productive operation using the machines, equipment, and tools consigned by the company in a responsible and safe way, respecting the safety and environmental rules.

The field of management is very wide and may be classified into the following categories: production, marketing, financial, human resource, purchasing, maintenance, and office. The emphasis of management, and consequently administration, has changed in the last decades. According to F. W. Taylor, "Management is an art of knowing what to do, when to do and see that it is done in the best and cheapest way" (Taylor 1911). While Taylor still is pointing out the economic component "cheapest way," modern definitions of management have changed to more holistic views, where the human resource plays a more important role. Koontz and Weihrich (1990) define management as the following: "Management is an art of getting things done through and with the people in formally organized groups. It is an art of creating an environment in which people can perform and individuals can co-operate towards attainment of group goals." In this definition the "people" play a central role.

Under a management environment where human resources are a central factor, safety and training play a key role in harvesting operations. The article wants to point out the role and importance of the human factor in forest management and how the social sustainability can be obtained by appropriated measures to guarantee occupational health and a high professional training standard of the personnel.

Human Resource Management and Administration

The administration has the function to establish the company policy and to determine the instruments how to operate the business to meet with the production goals (Boxall et al. 2007). The personnel of the different hierarchical levels working in an organization have their established objectives and try to reach these, always in accordance with the business culture and values of the company. The administration of a company represents the plan and ideas of the owners of a company, also in terms of return on investment of the applied capital. Decision taking makes part of the task of directors and managers, while the technical concepts provided for this process depend on the capacity of the employees, which are involved in the decision making. Decision taking is influenced by values, opinions, and visions of the higher administration levels. The hierarchical structure of the administration and the management in a company is shown in Fig. 1.

The objective of an efficient management is to obtain the best possible production result with a given input, increasing the efficiency of production. The management, no matter at which level or area of the production of a company, is a logic consequence of its administrational objectives and policies.

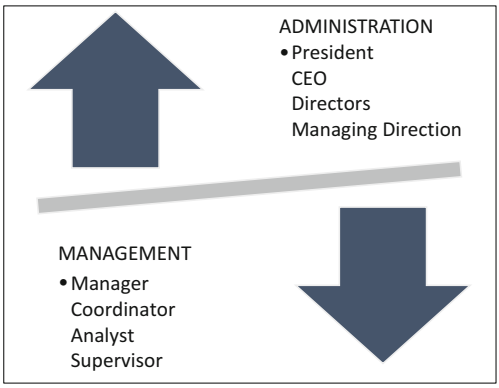

Fig. 1 Organization of administration and management with their different levels (source: the authors)

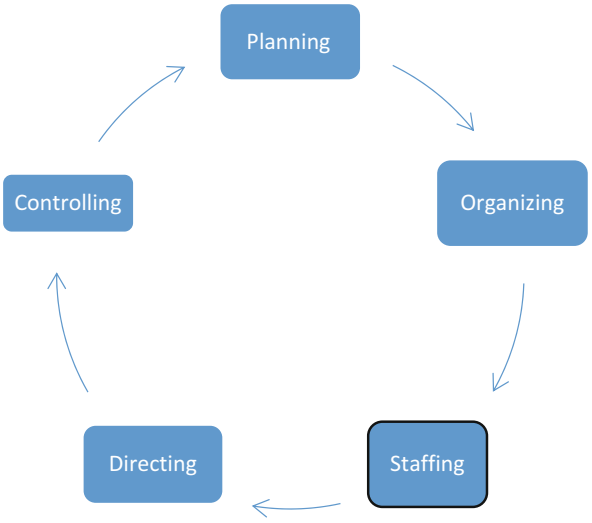

Fig. 2 The five pillars of management (After Koontz et al. 1980)

After Gulick (1936) management can be described by the keyword "POSDCoRB", where P stands for planning, O for organizing, S for staffing, D for directing, Co for coordination, R for reporting, and B for budgeting. Another description of the functions of management is given by Koontz et al. (1980), where the focus is on planning, organizing, staffing, directing, and controlling (Fig. 2).

The Five Pillars of Management

In the following the five pillars are discussed with the focus on harvesting operations, specifically for the safety and training issues of human resources.

Planning is the most basic activity of operational management. It is necessary for an adequate use of all resources available in a company to reach the production

goals or targets set by the administration. It is based on the questions what to do, when to do, and how to do. It bridges the gap from "where we are" and "where we want to be" (Koontz and Weihrich 1990).

Safety and training play an important role in this stage. Retraining, additional qualification, and advanced training have to be planned for the respective staff. Substitutes for the personnel involved in training have to be determined in advance to assure participation of the indicated employees. Safety instructions renewal or special courses have also to be considered in the planning process. These are only a few samples of the importance of safety and training in the planning phase. It is also important to plan the activities of the other "pillars." The instruments and frequency of controlling processes are very important for the success of the operations to be performed.

Organization is the next step, where the financial, technical, and human resources brought together to determine the best way to perform the operations. In this phase a kind of self-responsibility is passed to the members of the personnel of the different hierarchical levels. The organizational process includes the identification and classification of the activities and the assignment of the tasks. After Allen (1958) "Organizing is the process of identifying and grouping the work to be performed, defining and delegating responsibility and authority and establishing relationships for the purpose of enabling people to work most effectively together in accomplishing objectives."

Staffing is the pillar that gained more importance in the last decades. Higher degree of mechanization, stricter labor legislation, and controlling as well as more complex social behavior and interactions between people led to the necessity to fill open positions in harvesting operations with adequate and higher qualified personnel. Staffing involves manpower planning; recruitment, selection, and placement; training and development; remuneration; performance appraisal; as well as promotions of outstanding employees. According to Koontz et al. (1980) "Managerial function of staffing involves manning the organization structure through proper and effective selection; appraisal and development of personnel to fill the roles designed on the structure."

Directing or *Leading* has the function to put the outcomes of the three former "pillars" of management (planning, organizing, and staffing) in action. This part of the management deals with the elements of influence, guiding, subordination, motivation, and supervision. The main objective is to "influence" the behavior of the workers activities in a way that guarantees highest performance in the production process. This may happen by financial incentives or other methods. Guiding is the part of the working process where managers try to make the workers or employees accomplish the production targets. In this process conversation, training and information transfer are the crucial element of the communication.

Finally *Controlling* has to be mentioned to guarantee that the activities are in accordance to the goals set and that resources are used adequately and to show where the optimization potentials of the production process are. In this step productivity is measured, variations in the performance are highlighted, and correction procedures are defined to meet better with the company politics and targets.

The Importance of Staffing

The management pillar "staffing" is the one where working safety and training have to be implemented. For forest harvesting operations, productivity and working efficiency are the best indicators for evaluating the performance of the system. Productivity is defined as the transformation of production factors in goods, services, and/or capital. Efficiency on the other hand is the comparison of what is actually produced and the potential of what could be reached with the same resources (money, time, labor, etc.).

The objective of "staff management" is to select proper personnel for each function in the company activities and to perform appraisal and personal development to optimize motivation and productivity. After Koontz et al. (1980) staffing can be defined as "filling positions in the organizational structure through identifying work force requirements, inventorying the work force, recruitment, selection, placement, promotion, appraisal, compensation and training of people." The basis for an efficient management of human resource is to find the right person for the task.

For that purpose a precise and adequate description of the job profile is necessary, before the selection process can be done. In former times with manual or motor-manual harvesting operations, the selection of the workers was realized by a visual evaluation of the candidates. For higher positions also a personal interview was conducted. With the ongoing mechanization in harvesting operations, the jobs became more complex and so did the selection processes. For machines equipped with complex board computer systems allowing different operation modes, the operators are selected by sophisticated psychological tests and practical exercise, to detect the personal aptitude of a candidate. In tropical countries only a few training centers for harvesting machines exist. The operators in general receive an on-the-job training of the companies where they want to work. In this case the market only offers a low quantity of qualified professionals to operate machines, and personnel have to be qualified by the companies. In the case of occupying positions of supervisors and the management level, there are two possible sources for qualified personnel: internal recruitment with transfer and promotion of own employees or external source, where qualified candidates are found by advertisement, employment agencies, campus recruitment, or head hunters.

For optimization of production processes, improvement of the organizational development, and success by increasing productivity and efficiency, training of personnel to enhance skills of the labor force is a basic requirement. Training familiarizes and updates the employee with organizational mission, vision, rules, and regulations and the working conditions of a company. Existing knowledge is refreshed and enhanced. Workers are trained about the use of new equipment and work methods. When the objective of training is promotion of the employee, the training is given to familiarize the candidate with responsibilities of the higher-level job.

The benefits of training are the improved moral of employees, less necessity of supervision, fewer accidents, chances of promotion, and increased productivity.

Training methods may be separated in two basic principles: on-the-job and off-the-job training. The first training method is implemented in the daily working process and is a simple but efficient way of enhancing and updating working knowledge. Examples are job rotation, coaching, or temporary promotions. In the second method, the employees have to participate in special training courses, seminars, conferences, or workshops.

Remuneration plays also an important role in staffing. It is a monetary compensation of the employees for their work performance and, depending on the amount, leads to a higher motivation. Salaries may be based on a time or piece rate method. The time rate is linked directly to the time spent or devoted on the job. A predecided amount of money is paid per hour, week, or month. Since the remuneration is not directly linked to the productivity of the single employee, tight supervision is necessary, because the motivation to show a better performance in such a system is limited. The emphasis of the payment is more directed to quality than to quantity output. The piece rate method on the other hand is paid on a produced unit base. The employees are highly motivated to increase their productivity. In many cases quality suffers, the proper use of the raw material is not guaranteed, waste rates increase, and production costs may rise. According to Pynes (2009) a well-organized system of performance evaluation is necessary to get an overview about the productivity of each employee. Such a controlling allows to detect weak points in the organization, labor productivity, or in the motivation of the single employees or teams. Also it helps to detect the need for training and development and career planning and assist the companies' long-term human resource planning. Performance evaluation facilitates job analysis and recruitment efforts and is an important component for evaluating people skills, abilities, knowledge, and other characteristics according to the job that has to be done.

Harvesting operations can be considered as complex, since a couple of process steps have to be performed where a variety of different jobs, machines, and logistic concepts are involved. For the determination of how many workers are needed, a sophisticated personnel planning has to be conducted (Blombäck et al. 2003). The hierarchical structure has to be evaluated and the number of persons needed for each job has to be calculated. In general a few people have a coordinating and supervising function, but most of the labor force is directly involved in the operational part. Only focusing on the higher-level organization staff, the comparison of two harvesting systems of different size for an operation with 50 and 300 workers involved is given in Table 1.

While a harvesting operation with 50 workers can be organized and conducted with a leading staff of 8 people, an operation with 300 workers requires 35 employees of higher level. That indicates that the ratio of workers to administration and supervising staff is 1:6.25 for 50 workers and 1:8.6 for a 300 worker staff, respectively. The proportion of managing to operating staff reduces with the increasing number of people to be administrated.

The selection of the human resources needed may be defined as the search of "the right person for the right job." To find the right person for each job, a detailed job description must be available, so that a preselection of the candidates can be

Table 1 Example for the coordination and supervision personnel for two different sized harvesting operation systems (Source: Pancel 1993)

Operation 1: 50 workers	Operation 2: 300 workers
1 general manager	1 general manager
0 (or 1) general planner	1 general planner
3 administrators	10 administrators
1 or 2 managers	3 managers
3 or 4 group leaders	20 group leaders

done. If necessary, practical, theoretical, and psychological test have to be defined to choose the employees. Specifically high-performance machine operators in general receive an expensive training of several months to reach an adequate productivity (Vargas et al. 2002). If the wrong person with insufficient abilities is selected, the training costs and production loss may exceed an amount of 30,000 US$ (oral communication). The number of workers or machine operators in a harvesting operation is always higher than the managing staff. Operators of harvesters, forwarders, skidders, and chainsaws show the highest proportion of the staff. Supervisors, coordinators, or analysts in general are closely linked to a determined number of workers to be supervised during the operations, while higher-level employees like managers and planners are constant, no matter if a big- or small-scaled operation is conducted (Table 1).

Training and Motivation

Companies invest in training for improving individual productivity as well as the results of a harvesting team or the overall organization. This also may include training for higher safety or ergonomic issues, reducing this way the absence from work caused by disease and low motivation of the employees. Training in general is linked to teach and improve skills of lower-level workers and employees, while further education or professional development is used to guarantee high performance in the present and future of the management level (Bateman et al. 1998). To meet high productivity levels and efficiency is important for the survival of a company on the highly competed markets.

Training involves three processes: analysis of needs, development of an action plan, and evaluation of success. In a first step existing competences have to be analyzed and compared to those required. This can be done at the level of organization, groups, teams, or individual workers, involving managers, coordinators, and supervisors. At the organizational level, the purpose is to establish training priorities in the light of organizational strategy and associated core competences. At team level, the purpose is to ensure that a group of people involved in the same task possess the complementary skills required for effective performance and functional flexibility. At the individual level, a development review aims to match career aspirations with organizational needs (Winterton 2007).

The commitment which employees show in fulfilling their work tasks or the dedication they disclose reaching the targets is influenced by many factors.

The most important one is the motivation they have for doing their work. Motivation is the result of a complex interaction between the internal motives of a person and the external stimulation at the work environment (Maximiano 1991). Some theoretical approaches start from the premise that adequate opportunities and stimulations lead to the fact that persons do their work with more passion and enthusiasm (Gil 2001). The psychologist Maslow (1987) classified human needs in different power levels, where the first is physiological necessities, followed by safety, social, and appreciation, until individual fulfillment is reached. The psychologist Frederick Herzberg (1975) related motivation to working conditions like salaries, financial awards, policy of the enterprise, social status, safety at work, and supervision on the one hand and responsibility, admission, challenges, and opportunity for advancement on the other hand. According to Pynes (2009), process theories of motivation concentrate more on the cognitive and behavioral processes behind motivation. They suggest that a variety of factors may serve as motivators, depending on the needs of the individual, the situation, and the rewards for the work done. According to Rainey (2003), work motivation refers to a person's desire to work hard and work well – that is, to the arousal, direction, and persistence of effort in work settings. He further notes the variety of words used to describe motivation, which often overlap: needs, values, motives, incentives, objectives, and goals.

As already mentioned, selection and training of machine operators and workers for other activities in forest harvesting operations imply a high investment of time and money to the company. For getting a return on this investment, it is necessary to find the ideal profile for a determined activity, to find employees, workers, or operators that have good potential to be qualified for the designed activity. In forest harvesting operations, the competent operator produces according to the quality standards, while productivity is linked to the operational and mechanical efficiency of the machines or working equipment (Parise 2005). Knowledge of a person is linked to know-how and individual capabilities. Know-how is related with explicit knowledge, formal and specialized, data available, procedures, and drawings and based on a clear and practical application and it is shared. Capabilities are linked to tactical knowledge, acquired by practical training, personal accomplishment, professional skills, and private experiences. It is frequently transferred in a master-student relationship and generally is local.

Most of the factors that contributes in improving productivity can be fostered by training, qualification, and motivation of the staff. Using adequate equipment and machines, improving local organization, introducing planning and controlling of production, and having a better information flow or material allocation also are adequate tools to increase productivity and working satisfaction. According to Oliveira (1999), the repetition of a task, the training and learning by executing it, and experience lead to a better performance of employees and consequently a higher productivity.

In forest harvesting operations, this could be proven in many studies. No matter if the operator was working with a chainsaw or a high-tech harvesting machine, continuous practicing led to higher productivity. The more sophisticated the machine or equipment to operate is, the longer it takes until the operator reaches

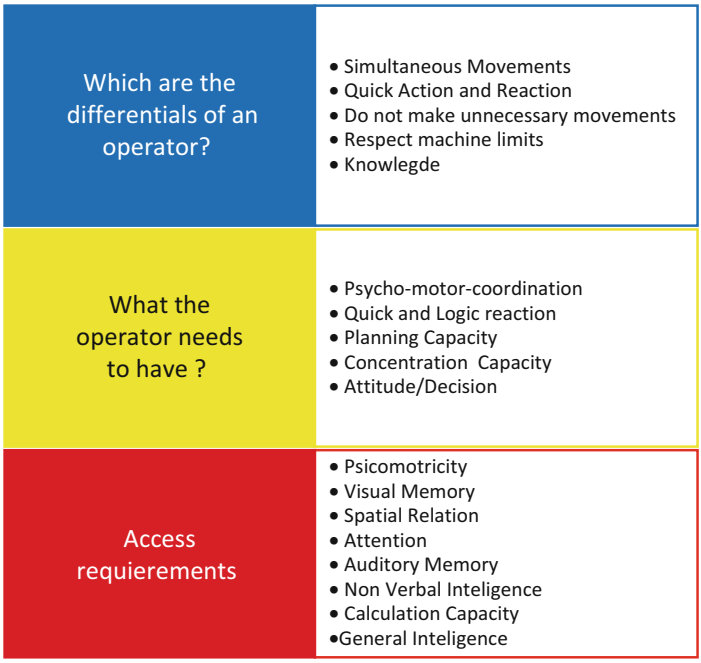

Fig. 3 Scheme for selecting machine operators (After Parise 2005)

its maximum performance. Heinimann (2001) analyzed a harvester driver and found that with small diameter trees the performance increases by 50 % within 1 year. Stampfer (1999) suggested a two-leveled learning: the first phase is called the learning phase, where the operator continuously increases his/her performance, while in the second phase, the operator is working at a relatively constant performance level. According to Parise (2005), operators of forestry machines need to be specially gifted with psychomotor skills, visual-based memory, stereoscopic vision, nonverbal intelligence, concentration, attention, and basic calculation to show a good potential to become a high-performance machine operator (Fig. 3). A detailed description of the profile of an operator, the mental characteristics, and the psychomotor abilities helps to select the right person for the right job.

After defining the personal capabilities an operator needs to have, the theoretically available skills have to be trained under professional supervision to reach the full capacity of a person for a given activity. Depending on the task, time for training and information to be passed to the candidate, may suffer alteration, or better, be adapted to the special function to be fulfilled. According to Parise (2005), the training of harvesting machine operators includes selection, physical health test, qualification, and final evaluation. Training has the function to qualify a person for a specified task or position by activating and improving skills. The results should be higher productivity, safety, and quality of the production. Studies showed that, for instance, a harvester operator by using a simulator in virtual training sessions could

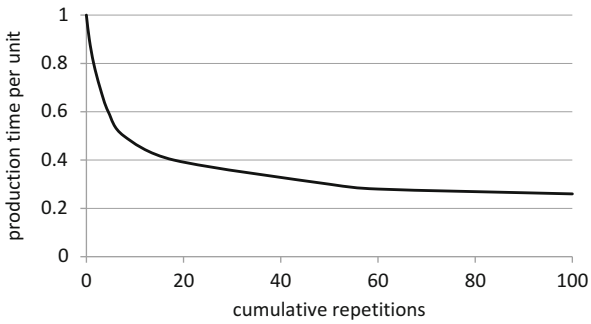

Fig. 4 Productivity and learn curve

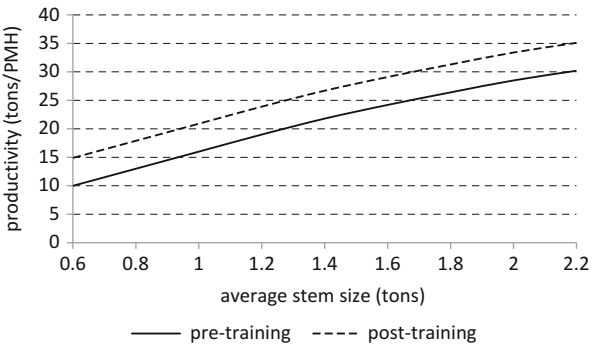

Fig. 5 Increasing productivity by training (PMH = productive man hour, after Haynes and Visser 2001)

improve his/her average productivity with the machine by 41.3 % as compared with the start of the training (Lopes et al. 2008).

The result of repetition by practicing and the time needed to produce one unit is shown in Fig. 4. The graph is also called "learn curve," indicating that only after a certain time of training or practicing a person reaches the maximum productivity.

Haynes and Visser (2001) showed that the productivity in a cable logging operation was based on the one hand on average size of the harvested stems and on the other hand on the training of the cable yarder team. For the average conditions in this study with a distance of 120 m, the average stem size of 1.2 t, and an average productivity before training of 18.8 t per hour, the training effect could be quantified as additional 4.9 t per hour (Fig. 5).

Working Safety

In the forestry sector, including the harvesting and wood transport operations, the risk of accidents, health damages, and dangerous situations is above the average level found in other productive sectors of the global economy. According to the *International Labour Organization* (ILO), about 6,300 persons die as a result of

working accidents or work-related health problems on a daily basis, summing up to 2.3 million dead people per year. According to the statistics of the ILO, more than 300 million accidents occur on the job every year, many of them resulting in absence from work for a considerable time. The human cost of this daily adversity is vast, and the economic burden of poor occupational safety and health practices is estimated at 4 % of the global gross domestic product (GDP) each year.

The average numbers of course show a strong variation between different countries, economic sectors, and also social groups. Most accidents and death cases are registered in developing countries, where a considerable proportion of the population is involved in the work of the primary sector like agriculture, fishing, forestry, or mining, generally considered as more hazardous activities. In these sectors, often women, children, or migrants of the lower social levels are among the victims. The forestry sector in tropical countries to large extend still is dominated by manual operations, including felling, delimbing, crosscutting, debarking, and loading. In general chainsaw operators are considered to be the group of workers running the highest risk. A survey conducted in Brazil in the 1980s by the authors showed a surprising result: the highest accident rate occurred in manual loading of the wood and the second place was occupied by accidents caused by snakes, spiders, and scorpions and only then followed the work with the chainsaw. No wonder that since these days the first activity mechanized was wood loading, the distribution of personal protective equipment, and the substitution of the chainsaw work by mechanized processes, where possible. But there are still many forest management projects in execution where no alternative to chainsaw work exist. Many of the forest operations cause health damages in the long term, not always recognized and detected as decease caused by ergonomic aspects in planting, carrying, or loading operations. The same is true for pesticides and fungicides used on seedlings, on trees, or in weed control in forest operations, which are also hazardous operations (Labour Department 2000). The hazardous forestry operations can be classified after their effect on the human body or mind, as there are mechanical, physical, chemical, biological, physiological, psychological, and social impact factors (Vahapassi 1988).

It took a long time for the interaction between working conditions and productivity being recognized by the industry and service providing sector. The first move in this direction started when managers in charge began to realize that occupational accidents had economic impact on the production costs, although at first only their direct costs (medical care, compensation) were perceived. In a further step also attention to occupational diseases was paid, and finally it was realized that the indirect cost of occupational accidents are up to four times higher than the direct costs (Vahapassi 1988). Examples for indirect costs are absence from work due to injuries or health problems, costs for witnesses and accident investigators, production loss, material damage, work delays, possible legal and other costs, and reduced output when the injured person is replaced and subsequently when he/she returns to work, among others.

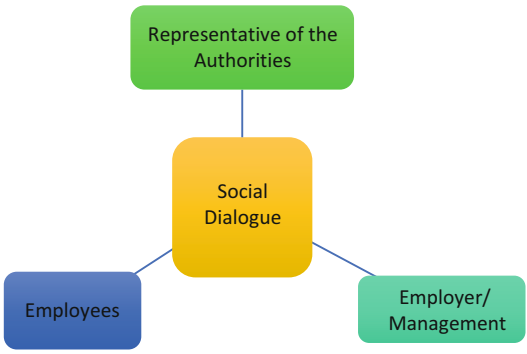

Fig. 6 Process of dialogue and decision taking for improving working safety (the authors)

To overcome the risks of working accidents, the companies should take proper actions. One important element is the participation of the workers of the dangerous activities to involve their opinion and experience in the decision-taking process (Fig. 6).

A basic element of safety is a well-developed health management, describing clearly the nature of hazards linked with the different activities in a forest harvesting operation. The steps the management takes to prevent and reduce the negative impact of such hazards and work-related accidents should be written down in a clear and simple language. The safety and health policy and related strategic objectives should have equal status with the enterprise's other policies and objectives and be explicit, operational, and amenable to monitoring and evaluation. The enterprise should be committed to meet or exceed all relevant regulatory and legislative requirements; be consistent with the enterprise's general policy and be periodically reviewed; and aim at fully integrating safety and health into the overall organization and operations of the enterprise. The safety and health policy and the management system for its implementation should aim, in the following order of priority, at eliminating the risk; controlling the risk at source; minimizing the risk by means that include the safe design of work systems and organization of work; and ensuring that personal protective equipment is used if, in spite of the provisions above, there is still an element of risk (Labour Department 2000). The most important instruments for a better risk management are supervision, monitoring, and controlling of the compliance of the safety rules of a company. If there is no self-responsibility of companies, the government should create an appropriated legislation to protect health and life of the citizens. Especially in forestry operations, a number of personal protective devices are available to protect workers against accidents. But not only providing the equipment and facilities is important, it should be combined with training and monitoring of the use of the protective devices and the safety behavior of the workers. One important instrument to be mentioned is the registration of accidents and near accidents. The control of occupational hazards in developing countries is, however, even technically difficult. Major part of the work is done in self-sustained agricultural activities, in small enterprises, or in the so-called gray informal sector, which implies that the number

Table 2 Responsibilities of employer and employees

Employer	Employee
Do not permit employees to work unsafe Empower supervisors with authority Enforce health and safety measures at work Ensure that supervisors have work-related safety training in the respective field Identify hazards and evaluate risks Provide and maintain a safe system of work Provide information, training, and supervision Provide the protective equipments to apply safety measures Undertake everything necessary to eliminate or mitigate all potential hazards: personal protective equipment (PPE) should be the last measure to be taken	Work according to the enterprise standards and comply with the health and safety rules Cooperate with the employer to enable him/her to comply with the respective action/duty Report any unsafe situation, near accidents or accidents to the employer or for health and safety responsible person Take reasonable care of their own health and safety and of others who may be affected by their acts (or omissions) To supervise and report about employees that put in danger the health and life of colleagues by not respecting health and safety rules

of individual workplaces is high and requires inspection and advisory resources to promote occupational health and safety (Mattila et al. 1994).

Principles of Occupational Health and Safety

To assure occupational health and safety for workers and employees, basic principles were implemented in most of the legislation in countries all over the world. First, the employer is primarily responsible for the health and safety of the workers. He must take the necessary protective measures, while the workers and employees themselves are obligated to use safety equipment and to behave according to the instructions given by the enterprise to ensure a safe and healthy environment. Last but not least, also the authorities have to verify if safety rules from both sides, employer and employee, are applied (Labour Department 2000) (Table 2).

Cause Analysis and Prevention of Accidents

About 80 % of the accidents are more likely to be caused by "the human factor." Human behavior, however, is determined by ergonomic factors as workplace characteristics, information and job instructions, situational/organizational factors, as well as individual factors. These factors can often explain why people take risks. A detailed work planning, considering ergonomic aspects, is an efficient tool against accidents (Lagerlöf 1977). As countries have different socioeconomic system, level of education, degree of mechanization, and climatic conditions, also these factors are discussed in relation to what preventive ergonomic approaches against accidents have to be taken (Blombäck 2003). The "human performance" depends on a variety of individual factors, if reliable evaluation is wanted.

Table 3 Risk of chainsaw work (After University of New Hampshire 2001)

Upper body		8 %	
Right body half	%	Left body half	
Right hand and arm	5	Left hand and arm	22
Right knee and thigh	2	Left knee and thigh	24
Right foot and leg	4	Left food an leg	21
Total right side:	***19***	***Total left side:***	***67***

Characteristics of the workplace, the working situation, individual attitude, and the personal environment of the employee have substantial impact on the performance of each worker and the way how he/she accomplishes with the duties at the job. Individual factors are age, work experience, personality, intelligence and psychomotor performance, motivation, and social standards, among others. More external factors, mainly influenced by the management and organizational pattern of a company, are decision making, design of machines, tools, materials, information, and job instructions. Situational characteristics describe the work environment factors and the working schedule (Lagerlöf 1979).

Accident preventive measures can roughly be divided into technical, organizational, and those directed to change human behavior (Lagerlöf 1977). As technological measures may be classified assignment of safety supervisors, elimination of physical factors, redesign of working processes in the work environment to influence individual performance or protective devices. As preventive measures to influence human behavior may be cited education, training or efforts at persuasion. In a final step restructuring organizational measures can help to prevent and reduce accidents. The implementation of administrative systems for human behavior control, such as production planning, remuneration system, or supervision and inspection, may also help to prevent accidents and health problems. The latter also includes establishing and maintaining procedures to identify systematically the risks to safety and health. For each task and activity in forest harvesting operations, it is recommendable to make a risk evaluation, identifying and recording the hazardous situations. The results should be processed statistically and reported periodically to the management and the employees (ILO 1998).

As an example may serve the accident and risk reporting of chainsaw operators as described in the "Safety and Timber Harvesting" guide of the University of New Hampshire (2001). There the average body contact with moving chain hitting points is reported and specified in detail (Table 3).

Training in Forest Harvesting Operations

All the staff involved in forest harvesting operations should participate in adequate training activities. The objective of training is to reach a professional level of high productivity and quality and, of course, a safe working environment. Since harvesting operations in general are teamwork, it is important that all the people of a group working together know all the activities or process steps of the operation.

The felling activities, for instance, could put in danger the people of the wood extraction or the personnel in charge of delimbing and debarking.

Training can be conducted "on the job" at the forest site but also in theoretical and practical courses. Safety training should be repeated in predetermined periods, always completed by the newest findings in near-accident and accident monitoring of the responsible persons for working safety and the training feedback of the participants. Critical situations should be highlighted more frequently in the training sessions than routine situations with danger potential. Another important tool in work safety is "introduction" to the working job. This feature is not only important for newcomers but also in the case of job rotation or changes in the operation procedures. Training effect to improve safety is most efficient when the general training level is low. If the present worker training in a job is about average, only a limited amount of improvement in production performance, however measured, can be achieved by increasing the average level of training to good or excellent (Lagerlöf 1979).

According to the rules of safety and health in forestry work, no person should perform forestry work if they do not have the required level of skill and knowledge. Unskilled persons, either new entrants to the industry or workers assigned to new jobs, are especially likely to have accidents. Effective training should therefore be part of the safety policy of the enterprise. Service providers such as contractors and their workers, self-employed people, farmers dealing with forestry, and woodlot owners may be disproportionately exposed to accidents. Mobile training units are a good way for providing access to training for professionals and semiprofessionals. The required level of skill and knowledge should be defined and objectively assessed through skills tests leading to certification by an authorized body. This procedure may be integrated with formal training or conducted at the worksite (ILO 2001).

- According to the "Code of Practice on Safety and Health in Agriculture," published by the International Labour Organization (ILO), the employers should have occupational safety and health competence (OSH) training to identify, eliminate, or control work-related hazards and risks (ILO 2001). Specific training needs can be identified by ongoing hazard identification, risk assessment, and evaluation of control measures by the workers during their activities. According to the ILO (2001), the training performed in a company should be:
- Adequately documented
- Conducted by competent and qualified persons
- Reviewed periodically by the staff in charge for safety and health requirements or by the employer in consultation with workers and their representatives and modified or adapted as necessary
- For all employees, temporary workers, service providers, managers, and supervisors involved in a determined activity
- Evaluated by the participants to guarantee comprehension and retention of the training content
- Adequate in content, language, training methods, and duration (time) and repeated in the necessary intervals

It is important that the workers exposed to the highest risks are reached by the training. An adequate method is to train people already working in practice and making them instructors by special advanced training, so that they can work as multipliers of knowledge and skills, accepted by the colleagues. In a study about chainsaw operators conducted by Hultberg (1987), highly skilled chainsaw operators were trained to be instructors in their working districts. They started to train their counterparts in their home region, reducing this way the occurrence of accidents by 50 % and health damages by 80 %, while workload was reduced and job satisfaction increased.

Safety Equipment and Safe Harvesting Operations

Where health and safety risks cannot be reduced to an acceptable level by training, instructions, and behavior rules, protection equipment should be provided to the workers to reduce risk for life and health damages. Safety equipment in harvesting operations is varied and available in a variety of technical accomplishment. There are simple protection means for manual operations, more sophisticated ones for motor-manual operations up to high-tech protection in purpose-built machines for forest harvesting operations. Modern machines specifically built for harvesting operations offer excellent protection and ergonomics to the machine operator, while the manual and motor manual in general are relying on personal protective equipment. Especially in tropical countries, this equipment is extremely important to reduce the risk of accidents and health damages. Even so, special training procedures have to be implemented in the harvesting operations to guarantee safety and to avoid accidents.

PPE: Personal Protective Equipment

Personal Protective Equipment (PPE) provides supplementary protection against exposure to hazardous conditions in forest operations where the safety of workers cannot be ensured by other means, such as eliminating the hazard, controlling the risk at source, or minimizing the risk (NYCOSH 2006). Suitable and sufficient PPE, having regard to the type of work and risks and in consultation with workers and their representatives, should be used by the worker and provided and maintained by the employer, without cost to the workers. The same level of protection should also be provided for casual or seasonal workers (ILO 2001). In some countries there already exist standards required by legislation for the use of PPE in forest harvesting operations. As an example, the PPE standards for employers and employees according to the Brazilian Ministry of Labor are cited (Table 4) (MTE 2001).

Employer and employees should evaluate carefully the use of PPE for each activity and the parts of the body endangered by the work. The parts of the body that are in danger in harvesting operations, according to the ILO (2001) are listed in Table 5.

All equipment used in harvesting operations should undergo appropriate testing to ensure that it is designed and constructed according to safety requirements of the

Table 4 Standards about personal protective equipment according to Brazilian legislation (regulation standard N° 6)

Employer	Employee
To provide the adequate equipment for a determined activity To request the use of the equipment Only provide equipment tested and approved by the national labor security agency To instruct and train workers in the proper use, safe keeping, and maintenance of the equipment To replace the equipment immediately when damaged or expired To be responsible for disinfection and maintenance Communicate problems or malfunction of equipment to the authorities Register the use and instruction to proper use in an adequate way	To use the equipment for the designed activity To use the PPE only for the work on the job To use PPE only for the work it is meant to To be responsible for a safe keeping and proper control of the equipment To communicate any problem with the equipment, doubts, or damages to the supervisor To accomplish with the instructions about proper use of the equipment

national laws and regulations (Firenze and Walters 1981). If such regulations are not existing, it is recommendable to use the standards of countries where forest work is done under comparable conditions. Equipment should be tested and certified to inform both purchasers and users about the quality and suitability of the equipment for the purpose for which it will be used. Testing and certification should preferably be performed only by institutions accredited by the competent authorities (ILO 2001).

Personal protective equipment may be uncomfortable for the user, specifically under tropical climate conditions. Additional weight, hot cloth or helmets, and heavy boots with steel bar are causing discomfort to forest workers and chainsaw operators and lead to rejection of the use of the PPE. According to Mayer and Korhonen (1999), to increase the willingness to wear protective equipment, the instruction and training must be effective and it must happen repeatedly. Positive feedback and the description of protection achieved have turned out to be effective in increasing the use. The use must be as easy as possible. It must be easy to get a device and there must be time to fetch it. Also the requirements to use must be realistic. In many cases the workload or environmental conditions can prevent the use of a protective device.

Safety Features in Forest Harvesting Machines

All machine producers have the duty to meet the requirements of the Driven Machinery Regulations (DMR) and General Machinery Regulations (GMR). According to these rules, machines used in forest operations must have:

- Proper guarding.
- Suitable protection against rolling over (ROPS).
- Protection against falling branches and trees (FOPS).

Table 5 Endangered parts of the body after harvesting activity (After ILO 2001, modified)

Parts of the body to be protected	Feet	Legs	Trunk, arms, legs	Hands	Head	Eyes	Eyes, face	Hearing
PPE appropriated	Safety boots	Safety trousers	Close fitting clothes	Gloves	Safety helmet	Goggles	Visor (mesh)	Ear muffs
Felling								
Hand tools	x		x	x	x			
Chainsaw	x	x	x	x	x		x	x
Mechanized	x		x	x	x			x
Debarking								
Hand tools	x		x		x			
Motor manual	x	x	x	x	x		x	x
Mechanized	x		x	x		x		x
Splitting								
Manual	x			x		x	x	x
Mechanized	x		x	x		x		x
Extraction								
Manual	x			x	x			
Chute	x			x	x			
Animal	x			x	x			

Mechanized								
Skidder	x		x	x	x			x
Forwarder	x		x		x			x
Cable crane	x		x	x	x			x
Helicopter	x		x	x	x	x		x
Stacking/loading								
Manual	x		x	x	x			x
Mechanized	x							
Chipping								
Mechanized	x		x	x	x		x	x
Tree climbing								
With chainsaw	x	x	x	x	x	x		x
Manual	x				x			

- Protection against penetrating objects such as branches, breaking cables, and chain shot (OPS).
- Brakes, tires, steering, and other control systems that are in good working order.
- Booms, grapples, cables, shackles, linkages, and chokers designed and maintained to cope safely with the loads in the case of lifting machines. Also maximum load should be clearly marked on the lifting machinery.

The machines have to be checked frequently according to the instructions of the producer and every time the operator changes. All machines have to be operated by competent and well-trained operators.

In tropical countries, these requirements are not always considered. Specially forest harvesting machinery was developed and built in other regions of the world, operating there under different working conditions. Operations in tropical forests often are technically more demanding: heavy load, three-shift systems, dusty environment, and permanent heat. The first specific wood harvesting machines imported from Scandinavia to tropical regions did not last very long. The cooling systems were not adapted to the hot climate, and air filters, hydraulic system, and other technical features were built for the use in boreal or temperate forests. In the best case only the engine blew up, but in many cases the whole machine started to burn, putting in risk the operator and other staff of the harvesting team. In the last decade, the machines did undergo a "tropicalization" process, where exactly these weak points were eliminated. The machines are much safer today, but special maintenance rules have to be implemented. More frequent washing to remove dust mixed with lubricants, oil, and residual biomass is recommended to reduce fire risk. Additional fire extinguishers or even automatic extinguishing systems are available on board to prevent damages in material and operators.

Machines are equipped with several safety features as cited above. The visibility of the cabins for safer operation as well as a better handling of the machines for more precise working improved significantly. Automatic leveling of the cabins and air-condition improved the performance, concentration, and attention of the machine operators and helped to reduce accidents and risks. These safety features in general made additional PPE unnecessary. Even so it is recommendable to provide this equipment to the machine operators. When they have to leave the machine for maintenance or a checkup, they should use a safety helmet and snake protection on the legs. In the case of harvester operators, the chain of the hydraulic chainsaw has to be changed every 2 working hours, where they also need to wear protective gloves. If the head is equipped with a disposal for chemical application of herbicides against resprouting, they also need protection against hazardous substances (ACGIH 1996).

Specific forest machines for harvesting operations are mainly used by bigger companies with the respective investment power. In smaller companies, service providers, farmers, or communities often use old, not specifically designed machines for forest work. Specifically in tropical countries, disused machines, mainly designed for agricultural use or altered trucks, are used for forest harvesting (Neitzel and Yost 2001). The main problems in regard to health and safety are:

- No cabins with protection features like:
  - Rollover bars
  - Protection against falling trees or branches
  - Secure glass
  - Seat belts
  - Noise and vibration reduction
  - Air-condition
- High balance point with risk of overturn with load.
- No automatic leveling of the machine or at least the cabin.
- Accessories are self-made and provisional and do not meet with the minimum safety requirements. Specifically winches are not equipped with protection against cable rupture.
- Loading operations with simple tools or constructions may be extremely dangerous.

In the case of the use of such machines, depending on the activity, the use of personal protective equipment may be recommendable. In any case it is necessary to improve training of the workers in terms of health and accident prevention. The obligatory use of helmet and protection gloves and keeping minimum distances to dangerous operations are absolutely necessary. Special training for using equipment at the limit (cables for winches, cranes for lifting, maximum loads) is highly recommendable to prevent serious accidents and health risks.

Another problem of using such wear-out machines is the lack of spare parts and maintenance conditions. In many cases the machines are not safe, without brakes, worn-out direction or with oil leakage. This causes additional risks to the environment and the forest workers, including fire, chemical contamination, or machine accidents, specifically in harvesting operations.

Safety Procedures in Manual and Motor-Manual Harvesting Operations

Motor-manual harvesting operations with the use of a chainsaw deserve special attention. This harvesting system is still the most applied in tropical forests. The use of chainsaws in felling, delimbing, crosscutting, and even debarking operations bears a high risk of injury, especially when used by untrained persons without proper instruction and missing safety equipment. Such conditions are often found in tropical countries leading to severe injuries and health problems of forest workers. Training of motor saw handling and adequate felling techniques help to prevent and avoid most of the risks associated with the use of chainsaws.

Many accidents already occur when carrying the chainsaw from or to the working place. Most of the accidents would be avoidable if some simple rules are respected:

- Keep eyes on objects that may cause stumble.
- Always carry the chainsaw with the sword backwards and in a protective cover.
- If moving with engine running, block the chain brake.

- Turn off engine when moving on steep slopes and keep the chainsaw away from the body.
- Use already all protective equipment, even if the engine of the chainsaw was not yet started.

For dominating correct felling techniques, the training is very complex. Especially in tropical forests, motor-manual felling operations are very complex because of the big-sized trees and the frequent occurrence of buttress. The motor-manual felling requires intense training and practice to be performed in a safe and efficient way. In the following the main steps in a checklist for a safe felling of trees with help of a chainsaw are described:

- Safety check:
- Check for correct maintenance.
- Check if all parts are mounted and secured in the correct way.
- Check if chain brake is working.
- Check for personal protective equipment.
- Before felling trees:
  - Consider factors such as wind, natural lean of trees, and large or dead limbs.
  - Plan the felling, considering an escape way in case of unforeseen happenings.
  - Felling is a one-man operation: all other persons have to be in a safe distance.
- Felling (see further instructions to the felling process)

For chainsaw operations, a lot of felling techniques exist. Some methods have even specific names, like Swanson, Pie, Directional, or Humboldt. Such techniques are often cited in chainsaw operator training sessions. The "Humboldt" method is considered as one of the safest felling cuts for chainsaws. For chainsaw felling, some specific terms are used. The "undercut" should be approximately 1/3 of the tree diameter, while the backcut is supposed to reach ½ of the diameter from the opposite side of the tree, being about 5 cm over the level of the undercut (Fig. 7). A hinge of about 3–5 cm should be left to guarantee the possibility of directional and

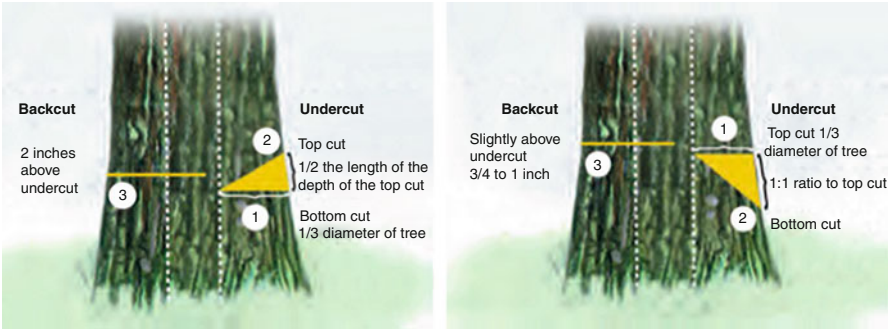

Fig. 7 Felling technique with top cut (*left*) and bottom cut (*right*)

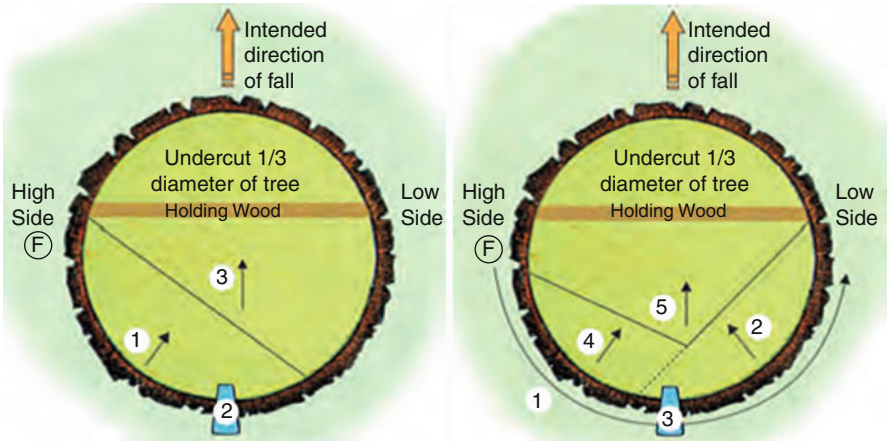

Fig. 8 Felling techniques with wedges using different combinations to perform the backcuts

slow felling. If the operator uses the saw to "cut through," the tree generally falls faster, and the operator has less time to bring himself to a safe position.

The safest way therefore is not to "cut through" but to leave a hinge and to use a wedge in the backcut while still sawing. The wedge can be driven into the cut with an ax keeping this way the cut open as well as directing the tree to the wished falling direction. The chainsaw operator only leaves the hinge intact, takes the chainsaw out of the cut, and turns the engine off. Then he/she fells the tree by driving the wedge deeper in the backcut until the tree starts to fall (Fig. 8).

Wedges and axes are important felling tools for chainsaw operators. The wedge prevents the tree from falling to the opposite direction. There exist several types of wedges made of different materials for different occasions and felling techniques. Big trees or "hanging" trees should always be felled by wedging them down, to reduce the risk of accidents.

For hanging or leaning trees that should be felled in direction against the gravity, wedges are indispensable. In extreme cases also the use of a cable skidder with winch is recommendable to prevent the tree from falling to unwanted directions. In such cases it is recommendable to form an asymmetric hinge, leaving more wood on the "high side" (Fig. 9). The felling techniques may show some variation according to the backcut and undercut performed.

In extreme cases it might be even adequate to use a hydraulic jack or a cable winch to get a directional felling (Fig. 10).

Motor-manual delimbing or snedding is the process of cutting branches of felled trees. While in deciduous trees and large conifers this term is used, for smaller logs with a straight stem (often plantation grown trees) also the term "snedding" is used. Motor-manual delimbing may be considered as the standard procedure for removing branches from all bigger trees felled in harvesting operations. Delimbing with a chainsaw is a risky and dangerous work. First because of the "kickback" of the chainsaw and secondly because of the difficulty to identify tension or compression

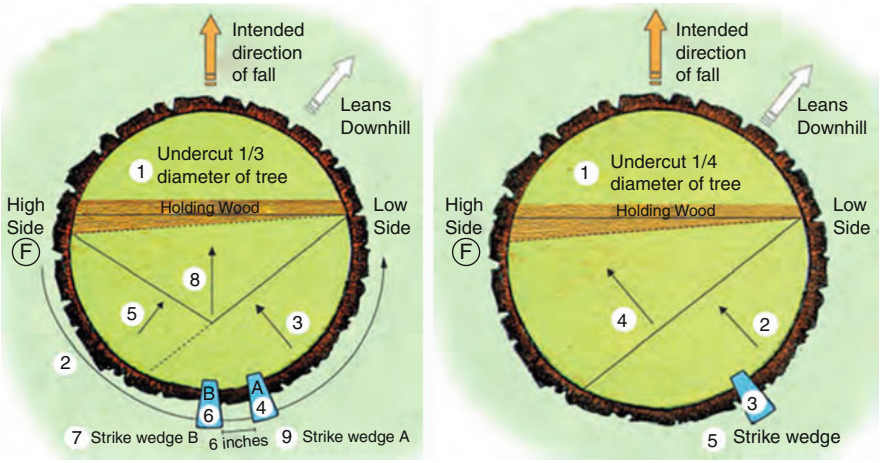

Fig. 9 Different cutting schemes for leaning trees

Fig. 10 Directional felling to avoid damages on remaining trees or improve safety of forest workers

of branches of the crown in felled tree. Some safety rules have to be considered for delimbing or snedding with a chainsaw:

Take a safe work position, working on the opposite side of the stem with the saw.

- It is recommendable not to move while sawing.
- Always stay on the upper side of the slope.
- Balance the chainsaw on the trunk or the leg to avoid fatigue.
- Always activate the chain brake when moving.
- Avoid cutting with the tip of the saw to reduce risk of kickbacks.
- Always hold the saw correctly positioned and with both hands.
- Cut large branches several times, always considering the weight and potential tension of the branch.

Fig. 11 Risky delimbing of branches in native forests with the help of a chainsaw (*left*) and in a planted forest with the help of small chainsaws with extension for improved ergonomic position of the workers

The process is a highly flexible way to remove the branches and crown parts of a felled tree and can be performed in any terrain and under any climate condition. The chainsaw operators have to be specially trained for this work since the risk of accidents is higher than in felling trees. For large tropical trees coming from native forests, it is difficult to calculate the productivity for this operation, since crown structure is highly complex and diversified. In general the operation is not that time consuming, because the standard procedure is crosscutting the stem at the commercial height, which is defined as the height before the crown starts. The crown itself remains uncut in the forest.

Another type of motor-manual delimbing is the use of a chainsaw with extension (Fig. 11). This type of motor-manual tool allows a highly ergonomic work with smaller trees felled, performing the operation in upright position and far away from the cutting part of the tool. It is used for cutting branches after motor-manual felling in forest plantations with steep terrain, where no mechanized operations are possible.

Debarking is another work in harvesting operations that may bear some risk for operators. If the work is done in motor-manual way in general, accessories for the chainsaw motor are used. Another operation is motor-manual bucking process in a harvesting operation. Making a crosscut in trees of big dimensions, like they occur in tropical rainforests, should not be underestimated. There is a high risk that the chainsaw gets stuck during the operation if the stem is not lying perfectly plain on the underground or if it is under any kind of tension. Since heavy and large trees can hardly be moved manually, it is important to train the chainsaw operators to perform the cut in the best way possible. After measuring the distance from the last crosscut

precisely to provide the correct length of the stem for further processing, the stem should be carefully checked for any tension caused by uneven underground. It is recommendable to cut the crown first, before doing the further crosscuts. In general the crown lifts the stem from the ground or causes other tensions in it. If necessary the use of wedges is recommendable and allows performing the final cut from underneath the stem or above, depending on the type of tension detected.

Maintenance of Machines and Equipment

Maintenance keeps machines and equipment in good conditions. This is extremely important for prevention of accidents, ergonomics, and health risks. Maintenance rules and instructions for machines and equipment have improved continuously in the last decades. Especially in the area of preventive maintenance, progress in operational efficiency and accident prevention could be achieved (Almqvist et al. 2006). The machine and equipment manufacturers today provide manuals and checklists for correct maintenance of their products. In the forestry sector, specifically in forest harvesting operations, manual and semi-mechanized systems are more and more replaced by completely mechanized systems to improve productivity and quality, reduce costs, and guarantee more safety for machine operators in the harvesting process. The companies working with these machines ask for maintenance plans that provide information about mechanical availability and efficiency of the machines, for calculating their operational costs, plan staffing and have information about productivity (OSHA 1992). Keeping the machine in good working conditions always reduces the risk of accidents and health damages to the staff working in harvesting operations (Axelsson 1998). In recent years high variability in the wear of machines, the mechanical availability, and operational efficiency of the same specification were detected. It turned out that the "human factor" is influencing significantly in the serviceability of the machines. It is already known that some operators perform better in terms of productivity than others, but also the maintenance intervals are influenced by the operators. To use the machine adequately and in a smooth way prevents from excessive maintenance and precocious wear-out. The wear-out can be influenced by training of the operators. Some training plans even foresee to train the operators not only in daily maintenance but also in preventive maintenance to let them know more about the specific wearing of a machine type and how it can be reduced by smooth operation and special care during work. If the machine is getting close to the calculated life span and the maintenance intervals cannot be kept anymore, the machine should be scrapped to avoid excessive costs.

Since the use of the chainsaws in harvesting operations of tropical forests is still very important, it is also appropriate to mention a few maintenance issues of this equipment. Chainsaws are considered as one of the most dangerous equipment in forest harvesting operations with high rates of accidents with serious injuries for the operators or causing severe health problems. This often happens because of wrong handling of the machine, which could be resolved by training, but partially it is due to wrong or missing maintenance of the chainsaw. First, it is important to select the right size of the chainsaw for the right activity.

Powerful and heavy chainsaws are required to fell big-sized trees, like they occur in native tropical forests. In forest plantations on the other hand, the trees often are of small diameter and can be felled with smaller chainsaws. Only choosing the machine of the right size often helps to reduce health problems and accidents. The selection of the chainsaw (power and weight) should be done according to the recommendations of the manufacturer for the respective tree size to be harvested.

When refueling the chainsaw, it is recommended to use the specification given by the manufacturer. The right fuel and the respective oil for a two-stroke engine are indispensable to reduce toxic exhaust gases of the chainsaw to a minimum. Working for hours inhaling this dangerous gases leads to headache, dizziness, and nausea. Inhaling the toxic gases over longer period may lead to chronic illness. Imperfect combustion increasing the amount of toxic gases is also due to wrong maintenance of the chainsaw. Air filter, spark plug, carburetor, and setting of the chainsaw have to be checked and adjusted/replaced according to the recommendations of the manufacturer. For filling in the gas and the oil, it is strongly recommended to use specific canisters that avoid spillage of gas and oil which later on may get into contact with the skin of the operator. To be exposed to such toxic substances over longer periods causes serious skin disease and intoxication. A serious problem often found in tropical countries is the lack of specific lubricating oil for the chains. Instead of adequate lubricant, waste oil from tractor engines is used. Besides causing serious environmental pollution, waste oil is highly toxic and always gets in direct contact with the skin of the worker during chainsaw operation. The canisters for gas and oil should be stored outside the danger zone of falling trees to avoid accidents.

For ergonomic questions, the maintenance of the chain is of crucial importance. Sword and chain consist of several flexible and fix parts that are important for the physical work the operator has to bring and also for the performance and productivity of the worker. Besides lubrication, the chain has to be sharpened correctly. The angle, the cutter tooth is sharpened has to be exactly after recommendation and the raker has to be reduced when the chain is wearing. The chain has to be changed if a tooth is broken or if the chain is reaching the end of its life span. A well-sharpened chainsaw pulls itself into the cut when felling the tree, while single-side sharpened chains often get stuck in a curved cut. One of the main causes for chainsaw accidents is the so-called kickback. This effect can be caused when the rotating chain is having contact with a solid object, causing an impulse in the opposite direction of the chain rotation. A good maintenance consisting of sharpening the angle correctly reduces the risk of such kickbacks. A good maintenance consisting of sharpening the angle of the teeth correctly reduces the risk of such kickbacks. In training session the chainsaw operators learn how to hold the chainsaw to prevent occurrence of kickbacks and how to position the body that it is always protected. The mechanical problems that may occur with a chainsaw are manifold, but it can be reduced with frequent and professional maintenance according to the manufacturer manual and own experiences under special working conditions. Checklists help to have always an optimal working equipment

available, reducing incident of near accidents, accidents, or physical distress. The most important items of a chainsaw checklist are:

- Check starter recoil and decompression button for functionality.
- Keep the sword clean and well aligned, replacing it if necessary.
- Remove dust, dirt, sand, or oil from the chainsaw after work or during the work.
- Clean or substitute air filter.
- Take care that the flexible parts always receive the necessary lubrication.
- Check the chain frequently for defects, sharpness, and tension.
- Check the chain break before starting the engine.
- Check the ignition and combustion system frequently for functioning.
- Pay attention to the functioning of the anti-vibration system.

First Aid: Training and Equipment

Forest operations generally are taking place on forest sites that are far away from cities and of difficult access. Since the forest work is classified as dangerous, it is important that the staff of a harvesting team is able to provide first aid in the case of accidents and injuries (KWF 2004). The training should include the procedures for helping in the case of open wounds, bone fractures, and revitalization. In areas where the work involves the risk of intoxication by chemicals or smoke; snakebites, insect bites or spider bites; or other specific hazards, first-aid training should be extended accordingly in consultation with an appropriately qualified person or organization. First-aid training, courses, certificates, and equipment that must be provided by the company or employer generally are stipulated by law. The company only has to contact the authorities to get the necessary information about first-aid requirements for the respective activity. Anyhow, in many tropical countries such laws are missing or not enforced by the local authorities. In this case negotiated agreements of the companies or employers should take place. The most important facts to consider concerning first-aid in harvesting operations are presented as follows.

First-aid training should be repeated frequently to ensure that the skills and knowledge of the employees are always up to date. Participation in the courses should be obligatory for all staff involved in the field work, not only the persons performing dangerous activities. The provision of first-aid facilities and trained personnel should be given by law, and respective regulations should be adapted by the companies. To provide first aid is not the end of the line after an accident, in fact the whole rescue chain in case of an accident with injuries of persons has to be planned carefully, including ambulance or helicopter transport to a hospital in an acceptable time.

Well-maintained first-aid kits or boxes should be readily available at the worksite and should be protected against contamination by moisture and debris. These containers should be clearly marked and contain nothing other than first-aid equipment. When opened for use, the material has to be replaced by an authorized person under the necessary hygienic environment. Periodic check of the content, validity of the material, and replacement should be scheduled and documented by a

person in charge. All employees and service providers interacting in the same operation should be informed of the location of the first-aid equipment.

The company should plan periodic meetings of the harvesting operating staffs, supervisors, mechanics, and managers to evaluate and assess the first-aid needs for specific activities. Especially if a harvesting system is changed, for instance, from a motor-manual felling to the use of harvesters, the first-aid training and equipment should be adapted accordingly. The consultation of workers and machine operators and their representatives should be done prior to any changes in the rescue chain. In bigger harvesting operations, distant from any hospital or medical facility, it might be appropriated to provide the harvesting staff with a team of paramedics or an ambulance on the location where the operation takes place. The reasonable practicability of having trained personnel readily available will depend on the number of persons involved in the harvesting operation, the risk and accident frequency of the specific activities, and the distance to the next facility with medical services. Where the respective indications are not given by the authorities and legal regulations, the company has to decide on their own and base on ethical principles about the minimum standards to keep in case of injuries or health problems of their employees.

The Role of Ergonomics in Health and Accident Prevention

Ergonomics are a multidisciplinary field of professional research with the aim of finding the ideal balance between the worker and its activity (Apud 1989). The main areas are anatomy, physiology, psychology, sociology, engineering, and management. According to the definition of the IEA (International Ergonomics Association), the ergonomics (or human factors) are the scientific discipline concerned with the understanding of interactions among humans and other elements of a system and the profession that applies theory, principles, data, and methods to design in order to optimize human well-being and overall system performance. The root of the term "ergonomics" is derived from the Greek words "ergon" (= work) and "nomos" (= laws). Today it is closely linked to work science and is a systems-oriented discipline which now extends across all aspects of human activity. Ergonomists that have to evaluate a work area, like a harvesting operation, must have a broad understanding of the full scope of the discipline. An ergonomic evaluation should promote a holistic approach in which considerations of physical, cognitive, social, organizational, and other relevant factors are taken into account. It should include the relations and regularities between work environment, the work itself, and the workers. The aim of practical solutions is to design the work, work environment, machines, and tools according to the human necessities and characteristics. This helps the workers to maintain their health and guarantees a high level of job motivation. Knowledge about working techniques, tools and machines, work environment and worker's capacity, motivation, and perceived effort helps to design the most efficient working environment with high productivity and good health (Harstela 1983).

The FAO (1992) already pointed out the poor working and living conditions for forest workers in most of the poor and developing countries all over the world. In many cases work efficiency under such circumstances is also poor. Heavy physical workload, inadequate working techniques, and tools often cause occupational accidents, diseases, and unnecessary fatigue, linked with low productivity and work satisfaction. In countries with available accident records, forestry appears to be one of the most hazardous occupations, with frequent and severe accidents and many diseases (FAO 1992).

Ergonomics may be subdivided into two basic elements: a technical and a human one. The technical element is based on the conditions of the work environment, machines, equipment, or tools, while the human factor is linked to the psychomotor and psychological characteristics of a person, its necessities, limits, or capacity to cope with the work in the job. Based on the analysis of these two elements, some criteria can be defined if, from an ergonomic point of view, a work or activity is acceptable or not. Among these are working safety, health, efficiency, remuneration system, social security, workload, and comfort at work and job stability. In the following the factors and characteristics of the activities in forest harvesting operations are evaluated that might be directly linked to safety and training of the forest workers.

Working Capacity and Workload

The capacity to perform physical work is influenced by a complex combination of factors. According to Astrand and Rodahl (1977), the factors conditioning physical performance can be summarized as follows:

- Energy output (aerobic and anaerobic processes)
- Neuromuscular function (strength and technique)
- Psychological factors (motivation and skill)

Symptoms of exhaustion because of excess of physical overload depend on the exertion during the execution of the working activities and the individual conditions of a person, like health status, number of daily working hours, nutrition status, or physical fitness (Minette et al. 2007). To the extend exhaustion increase, the working rhythm of the worker is reduced, capability to concentrate and think rationally decreases, productivity becomes low, and the person is susceptible for mistakes and accidents. All these symptoms are closely linked to the maximal capacity of the aerobic processes, so that this value may serve as an adequate indicator of the ability of a person perform to a specific physical work or activity. The aerobic capacity today is widely accepted as an international standard of reference for studying the fitness of people. The aerobic capacity can be assessed by measuring the maximal oxygen uptake ($VO_{2\ max}$), which reflects the combined capacity of the cardiovascular and respiratory system to obtain, transport, and deliver oxygen to the working muscles, as well as the efficiency of this tissue to

Table 6 Workload related to maximum aerobic capacity (AC) of the test person (After Couto 1987)

Workload	Workload in relation to maximum aerobic capacity (AC)
Low	Up to 25 % of AC
Moderate	From 25 to 37.5 % of AC
Heavy	From 37.5 to 50 % of AC
Very heavy	From 50 to 62.5 % of AC
Outermost hard	Over 62.5 % of AC

metabolize oxygen (Apud 1989). The measurement of $VO_{2\ max}$ is a relatively demanding procedure. Instead of oxygen consumption, the energy expenditure or work rate in watts can be used. Other methods include the measurement of the work output at a fixed level of oxygen consumption or fixed level of heart rate (Edholm 1979).

Couto (1987) published a work where he/she related workload classes according to the aerobic capacity of the test persons (Table 6).

In case a worker is exposed to hard or outermost hard work, his/her physical capacities are passing the limits and he/she needs adequate rests between two working sessions. It is important to know the time a person needs to recover from an overload. Since the easiest way to measure workload for an individual person is to take heart rate, an example for a manual wood piling operation is presented. To determine the recovery time for each activity, Lundgren (1946) took the heart rate of several forest workers for different activities linked to manual piling. He classified the work in five different activities: pulling the logs with axes, walking carrying logs on the shoulder, normal walking to the next log, walking unloaded and manipulating the logs on the pile. In total a period of 115 min was monitored (Table 7):

The table shows clearly the different workload of the activities expressed in the heart rate. Permanent work over a certain individual limit may lead to physical stress and wasting with danger of permanent health damage.

For estimating the time necessary to recover from each activity, the following equation developed by Murrel (1965) may be applied:

$$Recovery\ time\ (minutes) = \frac{W(b-s)}{b-1.5}$$

where:

- W = total working time in minutes
- b = average energy expenditure (kcal/min)
- s = energy expenditure adopted as standard (kcal/min)

The statements above are very important for safety, health, and training in tropical countries. In order not to overestimate the working capacity of workers when planning a harvesting operation in tropical regions, it is important to consider

Table 7 Mean heart rate and time spent in different activities while piling logs during 115 min. Activities: 1 = dragging logs with axes; 2 = ordering logs manually in piles; 3 = walking with logs on the shoulder; 4 = walking unloaded; 5 = recovery pauses

	Heart rate		Time	
Activity	Mean	Standard deviation	Minutes	%
1	118	12.7	40	34.8
2	112	4.9	11	9.6
3	117	6.1	20	17.4
4	106	6.2	9	7.8
5	94	8.1	35	30.8

the special circumstances found in the region where the harvesting activities take place. As already mentioned, the workers in tropical or poor countries may be different in strength and performance than people from industrialized and higher developed regions of the world. Size of the body, nutrition and health status, and metabolism of the organism are important to calculate the adequate workload for each activity. Besides these factors, also the climate may be considered. High temperatures, elevated humidity of the air, strong and frequent rainfall, or distinct drought seasons may also influence on the individual performance of the workers. Especially the heat is one of the limiting factors concerning hard work in the tropics. To regulate the body temperature, heart rate is accelerated to increase blood flow and to activate sweating through the skin. If personal protective equipment consists of special protective cloth, like it is the case for chainsaw operators, the problem becomes even worse. The person may reach their limit of heart rate without any additional work.

Other indicators to detect individual workload of a forest worker besides heart rate are the level of blood sugar and the body temperature. The control of the working environment for manual and motor-manual work in general is limited and has to be integrated in the productivity calculation of the workers. Adequate tools and equipment are important to reduce the workload and to guarantee safe and humane working conditions. For harvesting machine operators, the development of cabins with specific ergonomic requirements like air-conditions and safety features improved significantly working safety, comfort, and productivity of the operators.

Nutrition and Energetic Consumption of Forest Workers

Forest work is hard work with high energy consumption of the body. To guarantee the necessary energy input, a balanced nutrition consists of an adequate quantity of minerals, proteins, vitamins, fibers, and carbohydrates must be considered; correct alimentation for the forest workers is of extreme importance for working safety and for their health. In tropical regions people living in the rural regions in poor conditions, without adequate health care and balanced alimentation, often are the pool of workers hired for harvesting operations.

The effect of nutrition on working capacity is complex, but the most important relationship is concerned with the energy content or calorie intake. For short periods energy expenditure can exceed energy intake, and an accumulated deficiency of some 42 MJ does not appear to affect working capacity. Strehlke (1993) classified the forestry work as medium to heavy (approximately 12 MJ total energy expenditure per day) for most silvicultural jobs and as heavy (approximately 16 MJ total energy expenditure per day) for most logging jobs. Staudt and Pieters (1978) describe that the widespread insufficiency in nutrition must be expected to limit the energy amount available for work and thus reduce concentration, attention, and productivity of the worker and increases risk of accidents.

Edholm (1979) describes the most useful concept in considering nutrition and work capacity is that of calorie balance; the "extraction ratio" is a more informative index of the efficiency of food production. The ratio, introduced into human biology by Weiner (1989), concerns the proportion of total energy expended, which is devoted to food production. A detailed job analysis is needed and the calorie value of all food produced as well as the calorie value of all food consumed. Such information needs to be collected over a period of a year to cover not only seasonal changes in climate but also, more relevantly, the variations in physical activity on the land.

To meet with the hard to very hard workload, food during work time should be provided by the company. Besides the schedule for recreation of the physical stress, also correct alimentation is crucial to increase working safety and to reduce occurrence of accidents.

Another important issue is hydration of the workers under the climatic conditions found in the tropics. To drink enough liquid guarantees correct functioning of the organism and help workers to concentrate and pay attention to their activities.

The understanding of the importance of nutrition and hydration for work safety and health in many cases is not clear to the people. Training sessions should also include, in simple but comprehensive words, the importance of this issue.

Working Conditions and Human Needs

In forestry work under tropical conditions, the local living standard and health and nutrition status of the local workers have to be classified as even more hard and risky than in the boreal and temperate zones of the world (CNSST 2006).

The highly labor-intensive work with high workload is usually carried out by farmers and their families or hired local population, living mostly under traditional conditions in a poor state of health and nutrition. In many cases illiteracy is another important factor that influences on safety and training conditions. Forest work and harvesting operations after modern standards require a reasonable input of technical skill to achieve the safety goals in harvesting operations, no matter if it is on industrial scale or on a family level. Efficient organization of the forest work with acceptable effort and cost is important to meet fundamental ergonomic requirements. Ergonomics are usually overlooked in favor of low cost productivity or

Fig. 12 Pyramid or triangle of needs (After Maslow 1943, modified)

simply missing knowledge of basic context of influencing factors. Providing food for extra work and using techniques and methods demanding as little energy as possible, for instance, are simple and cheap measures to meet with ergonomic requirements (Strehlke 1979).

As already mentioned in the introduction to ergonomics, it deals with the complex interaction between the working environment and the other human necessities. To highlight the working conditions in the context of the overall living conditions, the pyramid of Maslow (1943) with the "hierarchy of needs" is used to understand human motivation in their working environment (Fig. 12). According to the theory of Maslow, all persons have different needs at different point of time in their life. These needs of humans can be arranged in a hierarchy, while individual persons move through the hierarchy by fulfilling each level of needs. Some people may have dominant needs at a particular level and thus never move through the entire hierarchy.

Maslow's hierarchy lists the following five levels of needs:

- *Physiological needs*: These are the basic necessities of human survival like food, clothing, and shelter. Without fulfilling these needs, a person will cease to function.

- *Safety*: Once the first level needs are met, a person feels the need to have a life of security where safety in all aspects of life is ensured.
- *Social needs*: This deals with the need to belong to a chosen social group or other relationships that are a part of human life. The need of being accepted prevents from negative effects like depression and loneliness.
- *Esteem*: Deals with the need to feel good about oneself and getting recognition from others to prevent inferiority complex and helplessness.
- *Self-actualization*: Becoming the best one can be. Here the need is to maximize ones potential.

The levels are presented in the form of a pyramid with the largest and most fundamental levels of needs at the bottom. According to Maslow, physiological, security, social, and esteem needs are deficiency needs or D-needs that arise because of deprivation. The highest level of the pyramid is called the growth needs or B-needs. Even if the hierarchies of needs are often criticized because cultural influence is not considered, the example might be adequate to explain the problems of the working conditions linked with harvesting operations in tropical forests. People working in tropical forests or workers hired for harvesting operations often are coming from poor conditions with low living standard. Before they think about safety or productivity, their basic needs like food, sleep, and health have to be fulfilled. Companies and employers should take care of these basic needs if they want to have highly motivated workers. In the case of farm or community forestry, the government should take over the part of the supervisor and take political measures to improve living standard and education of the people living in the rural regions. At least food and adequate lodging under safe and sound conditions should be guaranteed to make the workers susceptible for safety issues and training in forest harvesting operations.

Safety and training in harvesting operations are an important issue as all the current research, new legislation, and efforts of companies and governments show, especially in poor countries in the tropics. Accidents with severe injuries and death are still very common. But there is still a long way to go before training and safety instructions reach standards of developed countries, which is also due to the different working conditions under tropical climate. A trend toward mechanization is a good indicator for substituting hazardous manual and motor-manual operations by safer and higher productive systems (Malinovski et al. 2008). Some of the motor-manual operations probably never will reach a level that at least deadly accidents may be completely extinguished.

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