Proceedings of the IUFRO / FAO Seminar on

Forest Operations in Himalayan Forests with Special Consideration of Ergonomic and Socio-Economic Problems

held October 20 - 23, 1997
in Thimphu, Bhutan

edited by
Hans R. Heinimann
John Sessions

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Forest Operations in Himalayan Forests with Special Consideration of Ergonomic and Socio-Economic Problems

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Contents

Preface

The seminar held in Bhutan between October 20 and 23, 1997, was the 3rd seminar of IUFRO 3.06.00 held in Asia - following the seminars of 1987 in Peshawar/Pakistan, and of 1994 in Harbin/China. In keeping with the aims of IUFRO, the Bhutan seminar aimed:

- to bring together an international group of researchers to discuss how to improve the efficiency of forest operations in the mountain forests of the Himalayan subregion;
- to exchange experience among scientists, professionals, and government representatives;
- to create better understanding between scientists from various countries and cultures.

Why did we choose Bhutan as a place for a scientific meeting? IUFRO research group 3.06.00 focuses on problems of mountain forestry what means - from an operational point of view - non-trafficable terrain conditions. It tries to organize its meetings in the most significant mountainous areas of the world. The Himalayan subregion was on the wish list for quite a while, and it was good luck that one of the officers, Dr. Guglhoer, who has worked in different places of Asia was in Bhutan at the time making it possible to organize this meeting.

The significance of mountainous areas is becoming more and more important. Estimates of the United Nations tell us that in 2010 about 40% of the world population will live in mountainous areas and in areas influenced by mountains, respectively. The management of the fragile forest ecosystems in those regions is a key issue for a sustainable development, as proclaimed at the RIO World summit in 1992. Bhutan is an excellent case study of a very fragile region due to its geologically very young history and its richness of natural heritage, why it was nominated as one of the world's hotspots of biodiversity. Furthermore it is well known for its environmentally sound forest practices that probably could represent a model case for many developing countries.

In a modern understanding sustainable development is based on three principles: economic development to fulfill human needs, social development following the principles of equity and human integrity, and conservation of our natural resources such as limnosphere, atmosphere and biosphere whereas maintaining biodiversity is a key issue. These three principles cannot be treated separately, they have to be considered in an integrated way. That is why IUFRO research groups „forest operations under mountainous conditions“, „ergonomics“, and „environmental effects of harvesting operations“ have begun organizing joint meetings.

IUFRO promotes the dissemination and application of research findings in developing countries. Scientific knowledge is not a value to be conserved by a single person, a single institution, or a single country. It's a heritage of the international community. I hope that the Bhutan event is a starting point for the exchange of experience among scientists, professionals and government representatives that will evolve to a common path in the future.

The process of globalization has been changing economic, scientific, and social life dramatically. The change will continue in the near future. Economic and social activities will be integrated in an interrelated international network binding together different nations. We therefore need to create a better understanding between different cultures. I am sure that visiting Bhutan could help the participants of the seminar to improve the understanding of cultural and social life in the Himalayan subregion.

I would like to thank the Royal Government of Bhutan warmly for making it possible to organize a scientific meeting in Thimphu including an excursion giving us an idea of the real conditions of forestry out in the field. I know how much additional work had to be done to handle all the preparatory activities and to make all the necessary arrangements. I would like to address a special thank to the following persons:

- Mr. Phuntsho Namgyel, Program Coordinator for Forestry Research, who is the responsible person from the Ministry of Agriculture of the Royal Government of Bhutan;
- Dr. Wolf Gughlhoer, Co-Manager of the Integrated Forest Management Project and Coordinator of IUFRO Working Party 3.06.01 “accessibility of mountain forests”;
- Prof. Frits Staudt, coordinator of the IUFRO Research Group 3.07.00 „Ergonomics“ for supporting this joint seminar.

Without their assistance it would not have been possible to organize this conference.

Hans R. Heinimann

Coordinator, IUFRO Research Group 3.06.00 “Forest Operations Under Mountainous Conditions”

Part 1

Official Addresses

Innaugural Address

Dasho Khandu Wangchuk Dy. Minister, Ministry of Agriculture, Thimphu, Royal Government of Bhutan.

Distinguished Delegates, Colleagues, Guests, Ladies and Gentlemen,

Let me begin by extending our warmest welcome to the eminent forest scientists gathered here on behalf of the people and the Royal Government of Bhutan. We thank you for honouring us with your presence in our country and for the high privilege bestowed on us to host the third IUFRO and FAO Seminar on forest operations in Himalayan Forests - a topic which is of high relevance and importance to not only our foresters but for all Bhutanese.

We hear and read everyday of many environmental alarms raised such as that two-thirds of the world's original forest has disappeared and that it continues to disappear at an astronomical rate and of the dire consequences of this phenomenon to not only human welfare but ultimately to its survival on this planet. The forests, once unlimited and free natural resources, have today catapulted to the center stage of world politics, demanding international understanding, co-operation and action to arrest destructive deforestation and to manage what is left on a sustainable basis.

The fear, the worry and pain of deforestation are real. We people, living in the mountains more than others, know and understand what happens when forests are absurd and destroyed. We also know the additional consequences of such actions of ours on our fellow beings living in the low lands. Such a scenario cannot be more poignant than in the Himalayan mountain ranges which are the source of many great river systems in south Asia where we hear of land and wood resources degradation, loss of life and property due to floods and heavy siltation in water reservoirs.

Here in our country, under the wise, far-sighted and dynamic leadership of our monarchs, we have achieved phenomenal socio-economic development in the last three and half decades. Our development philosophy ascribes the highest value to the conservation of our natural and cultural heritage. Our king, His Majesty Jigme Singye Wangchuck has stated that :

"Throughout the centuries the Bhutanese have treasured their natural environment and have looked upon it as the source of all life. The traditional reverence for nature has delivered us into the twentieth century with our environ-

ment still richly intact. We wish to continue living in harmony with nature and to pass on the rich heritage to our future generations."

The cardinal statement in our forest policy is of revenue generation being secondary to conservation and protection of forests. The Forest and Nature Conservation Act of 1995 stipulates that all forest harvesting operations are to be strictly based on management plans and sound ecological, social and economic considerations.

While undertaking harvesting operations, we strive to build roads that do not damage the environment, adopt environmentally friendly felling and extraction systems to facilitate natural regeneration, plantations and towards maintaining the biodiversity.

The policies and strategies laid down for sustainability combined with the rugged terrain, low level of technology available and other resource constraints pose considerable challenges to utilization of forest resources. It is in this direction, that my colleagues and myself are most happy with the holding of this Seminar in our country.

Over the next few days, while sharing our aspirations, experiences, problems and successes with you during the seminar and field visits, we are looking forward to learn from you and your experiences in areas like road planning and engineering, extraction technology, ergonomics, integration of forestry and rural development.

On behalf of the 120 million people living in the Himalayas, the people and the Royal Government of Bhutan and on my own behalf, I would like to thank the international Union of Forestry Research Organizations and its members for the interest and concern shown on Forest Operations in Himalayan Forests. We have noted with gratification and appreciation that most of IUFRO's members and above all, that all of you - the distinguished participants - are not from the Himalayan region. Your interest in the subject is therefore of wanting to support national efforts in establishing cost effective, environmentally friendly and sustainable forest operations in the region where on the one hand, there is limited know how, limited resources for the required investment required and the ecology is highly fragile and on the other hand, operations are costly.

We thank each and every one of you for your concern and support and would like to assure you that on the part of the Royal Government, we will continue to protect the fragile ecology of our mountains and undertake forest operations that are sustainable and environmentally friendly. You can return to your countries in a few days time with the satisfaction of having contributed substantially to sustainable forest operations in a country which has a large part of the Himalayan forests.

May I add here, that we consider this seminar as a starting point for a fruitful collaboration in the coming years with the institutions you represent and with you. It is clear that for sustainable utilization of forest resources, global as well as local actions are required and that the two are integral parts of mankind's efforts to save our planet Earth.

In concluding, I would like to wish you successful deliberations and an enjoyable stay in our kingdom.

I would also like to express my sincere appreciation and thanks to my colleagues led by Phuntsho Namgyel, Officer-in-Charge, Renewal Natural Resources Research Centre, Yusipang who have worked hard on the logistic and other arrangements for this seminar.

I now have the pleasure of declaring the seminar on Forest operations in the Himalayan Forests opened.

FAO welcome address

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Honourable Deputy Minister, Your Excellency Dasho Khandu Wangchuk, Prof. Hans Rudolf Heinimann, Prof. Frits Staudt, Dasho Kinzang Dorji, Mr. Phuntsho Namgyel RNRRC Yusipang, Dr. Wolf Guglhor, Colleagues, Ladies and Gentlemen

It is a great honour and pleasure for me to convey to all of you the warmest greetings and best wishes for successful meeting from Dr. David Harcharik, Assistant Director General of the Forestry Department FAO, Food and Agriculture Organization of the United Nations.

First of all I wish to express the gratitude of the organization to the kingdom of Bhutan who is hosting this important event which I am sure will provide an excellent opportunity to exchange information and experience on recent developments in forest engineering and harvesting operations with special reference to problems and solutions encountered in the Himalayan region.

I would also like to thank Prof. Henimann representing IUFRO Subject group 3.06, for the continued cooperation with FAO in the field of forest operations and for all his efforts bringing together so many high level specialists from various parts of the world. I believe this is very important pre-condition for a most successful, interesting and productive meeting.

FAO has a long standing cooperation with IUFRO particularly in the subject areas on forest operations in steep terrain and forest operations in the tropics. IUFRO and FAO cooperated in series of workshops, seminars and symposia dating back to the early 1980's. Some of the more recent cooperating projects were :

- International Seminar on Forest Operations under Mountainous conditions in Harbin, China in 1994;
- Workshop on Forest Codes of practice contributing to Environmentally Sound Forest Operations, Feldafing Germany, 1994 ;
- Satellite Meeting on Research on Environmentally Sound Forest Practices to sustain Tropical Forests in conjunction with the IUFRO XX World Congress, Tampere Finland 1995 ;
- Seminar on Environmentally Sound Forest Roads and Wood Transport, Sinaia Romania, 1996.

In all these meetings and workshops important contributions have been made by leading researchers in the field of environmentally sound forest utilization management and conservation. Proceedings of these meetings have been widely distributed in order to facilitate the application of innovative research results improving forest resources utilisation, reducing wood waste in the forests, increasing forest yields and decreasing environmental impact on forest stands and soils.

This seminar is a further important step in collecting and disseminating information, exchanging the experience of research results and pursuing ways and means to transfer these research results into practical applications.

You are very well aware that the worldwide debate on conservation, sustainable utilisation and management of forests and natural resources has taken a new dimension in so far as the question arises whether in the new millennium forests will be sufficient to cover the increasing needs for goods and services from forests for future generations.

Forestry has received a major attention at the United Nations Conference on Environment and Development (UNCED), held in Rio de Janerio, Brazil in 1992 . Under Agenda 21, chapter 11, entitled "Combating deforestation", deep concern has been expressed at the threats forests are facing worldwide and the consequences of forest loss and degradation.

As a result of UNCED, action programs have been proposed in the field of forest conservation, management and utilisation :

- Sustaining the multiple roles and functions of all types of forest lands and woodlands.
- Enhancing the protection, sustainable management and conservation of the forest, and the greening of degraded areas, through forest rehabilitation, afforestation, reforestation and other rehabilitative measures.
- Promoting efficient utilisation and assessment to recover the full value of goods and services provided by forests, forest lands and woodlands and
- Establishing and/or strengthening capacities for the planning, assessment and systematic observations of forests and related programs, projects and activities including commercial production and trade.

Ladies and Gentleman, please permit me very briefly to mention some of the initiatives taken by FAO to promote environmental sound forest harvesting and engineering practices improving forest utilisation, reducing costs and the environmental impacts supporting sustainable forest development.

Application of the FAO Model Code on Forest Harvesting Practice and assistance to FAO member countries to develop local, sub-regional and regional codes to enhance environmentally friendly, economically viable and socially acceptable forest operations.

- Case studies on reduced impact harvesting operations, comparing conventional and improved technologies, analysis benefit and costs of such operations.
- The FAO Forest Harvesting Bulletin, which has been established to create a global network to facilitate the dissemination of information and experience in the field of forest harvesting practice.
- Environmental impact assessment related to forest utilisation. This project plans to develop a new system for collection, analysis and dissemination of information related to the impact of harvesting operations on the forest resources of the world.
- Program on environmentally friendly engineering. The aim of the program is to collect and disseminate information to road planners, supervisors and technicians, enhancing environmentally friendly forest road design, and construction techniques. This will be done through seminars and workshops, as well as case studies and through publications.

Your Excellency, colleagues, Ladies and Gentleman, let me once again thank all of you for your contribution be it as a host, organizers, Lecturers and/or participants to make this seminar a most fruitful and an outstanding contribution to enhance sustainable forest resources, management and utilisation.

Closing Address

Lyonpo C.Dorji Chairman of the Planning Commission and Minister of Planning, Royal Government of Bhutan.

Your Excellencies, Distinguished Participants, Ladies and Gentlemen

It gives me great pleasure to address this August gathering, at the closing ceremony of this very important seminar. We are highly honored to have been able to host this international seminar on “Forest operations in Himalayan Forests”, which is the first one of its kind ever held in the Kingdom. It is only benefiting that such a seminar focusing on the Himalayan Forest should take place here in Bhutan with its large tracks of virgin forests and it still pristine natural environment. As someone with a forestry background, I am particularly pleased see that so many eminent scholars, scientists, researchers and foresters from various countries were able to attend this seminar.

I understand that you have had a very fruitful meeting as is also evident from the summary and recommendations just presented. You have deliberated on a wide range of subjects from purely technical and practical topics to ergonomic and socio-economic studies of academic interest. Over the next few days on your post seminar tour, you will have the opportunity to substantiate and relate some of what you have been discussing with field situations and realities. All in all, I am convinced that this seminar would have highly enhanced the capacity of our Forestry Services Division and other research and development agencies in managing our forests and our natural resources on a sound and sustainable basis. I am sure that our international delegates have equally benefited from the exchange of information, knowledge and experiences with our national participants.

Ladies and Gentlemen, being in the Himalayan region, our kingdom has rugged terrain with a very fragile ecosystem, which necessitates that our development policies on the use of our natural resources, especially minerals and forests are cautious. Our policy has been targeted at promoting sustainable utilization of these resources in the long term, thus foregoing the short - term economic gains and benefits so that we do not pass on a bad legacy of damage control to our future generations. Further, in order to meet the demands of our rural people and to pursue development on our own terms and at our own pace, we are committed to an integrated approach towards the management of our renewable natural resources. To this end, our Ministry of Agriculture responsible for agriculture, livestock and forestry development is organized along functional lines so that development of one sub-sector takes due cognizance of impacts and implications on the other sub-sectors. Although, our experience is rather limited, we are convinced that it is the right approach as increasingly recognized by our development partners and other institutions within and outside Bhutan.

The integrated approach, however, does not mean that we have less stringent forestry policies. Currently, we have 72.5 % of our geographical area under forests ranging from sub-tropical broadleafs to temperate conifers to alpine scrubs. Our Forest and Nature Conservation Act, 1995, endorsed by the National Assembly during its 73rd session has mandated that the kingdom must maintain at least 60 % of our country under forest cover for all times to come. Similarly, we have declared 26.23 % of our geographical area as protected consisting of nine nature reserves, national parks and wildlife sanctuaries to conserve our rich biological diversity. For your information, Bhutan is known to harbor approximately 7000 species of vascular plants, 160 species of mammals and more than 770 species of birds.

As you may have already heard during the course of the seminar, utilization of forest resources in Bhutan is based on scientific forest management plans. These plans prescribe strict social, economical and environmental standards based on comprehensive socio-economic, biological and geophysical surveys. We are aware that an ecosytem once disturbed will never be totally restored but through measures such as these, we hope to mitigate the adverse impacts of forest operations. An important consideration of our forest management plans is to ensure that our people have continued access to the sustainable utilization of the forest resources and that their livelihood is enhanced and not threatened.

Under the dynamic and farsighted leadership of our King, His Majesty Jigme Singye Wangchuck, we have deliberately embraced a cautious policy towards development in general and towards the development of our natural resources in particular. We would like to carry out development at our own pace, commensurate with our own capacity while learning from the experiences of those who have trodden the development path earlier and not be lured into the world of consumerism and materialism. To demonstrate our will and commitment to this development philosophy, the policy of the Royal Government has been to establish only industries which are sustainable and environmentally friendly. Thus, despite financial constraints confronting the Royal Government and in spite of the potential for generating revenue from forests in the short-term, the utilization of our forests are being minimized consciously for the sake of future generations.

Ladies and Gentlemen, I do not expect you to subscribe to our principles and policies entirely, but I do hope that you will take back with you the cardinal message that we in Bhutan are committed to ensuring sustainable use of our forests and other natural resources and continue to nurture our environment by not only drawing on modern science and technology but also on our proud tradition of revering nature and our unshakable faith in the sanctity of all living beings.

Finally, let me congratulate the organizers for successfully staging an event of this magnitude here in Bhutan. I consider this as the beginning of a new era of cooperation among individuals, institutions, agencies and countries devoted to the sustainable management of the world's ever dwindling forest resources. I am sure, our foresters in Bhutan, have benefited immensely from this seminar and would go on to benefit from the personal and institutional contacts established with the international participants during the course of this seminar. Let me wish you all a pleasant and rewarding field trip over the next few days and a safe journey back to your respective countries.

Part 2

Forestry in Bhutan

Forest Management in Bhutan

D.B.Dhital Forest Management Planning Officer, Forest Services Division, Thimphu, Bhutan.

ABSTRACT

About 70% of Bhutan is forest land covering an area of about 3 million hectares. The paper gives an overview on the approach of the Royal Government of Bhutan to manage its forest resources and to implement forest management plans.

Scientific forest management started in 1964 when Indian professionals developed the first management plan in Bhutan. During the seventies the Forest Service Division FSD of Bhutan became responsible for the planning activities. At that time the planning procedures were quite technical omitting community involvement and other social aspects. Management units usually consist of an area of 10’000 to 20’000 hectares. At the beginning of the nineties planning procedures were adapted taking into account aspects of social forestry. A program was established to encourage private and community forestry.

KEYWORDS--*forest management, Bhutanese forestry, social forestry, community forestry, management plans.*

INTRODUCTION

Scientific management of forests started in Bhutan with the preparation of first forest management plan in 1964. Mr. P.C. Dutta Purkayastha, an Indian Forest Services Officer, on assignment to Bhutan, prepared the first forest management plan for Sarbhang forest division. The duration of the plan was for ten years (1964-65 to 1973-74).

One year later, the same author prepared the second working plan for Samchi forest division. These plans have been prepared meticulously, as during those days, there were lot of difficulties in getting reliable data. However, both the plans lacked, very much, in socio-economic information of the area.

During the 1970's, management plans were prepared by Forestry Services Division (FSD) with the technical assistance from UNDP/FAO Projects. Mr. Harry J. Mc Carty, an American forester prepared a plan for another management unit, called Chimakoti forest management unit. The duration of the plan was for a period of ten years (1976 - 1977 to 1985 - 1986) He drastically reduced the format of the plan which looked very simple but some of the required information were lacking. He also did not look on the social aspect of the plan. The community role of the forest, the local peoples' dependence on the nearby forest etc. were not considered. Sizeable sections of the plan was devoted to the logging aspect alone without giving due importance to the socio-cultural aspects. Only from the beginning of the 1990's was there a slight shift in the management planning system. More considerations were given to the social aspects. The prescriptions were drawn based on the forest functions, which were identified in the field and on the map.

FOREST POLICY

There are four guiding statements of the national forest policy. The purpose of the policy statement is to ensure that forest resources are used according to sustainable principles, contributing to social justice and equity. Further the policy will primarily ensure conservation of the environment, and only thereafter aim at derivation of economic benefits from the forest as a rationally managed resource. The ***policy statements*** are given below, in order of priority.

- Protection of the land, its forest, soil, water resources and biodiversity against degradation, such as loss of soil fertility, soil erosion, landslides, floods and other ecological devastation and the improvement of all the degraded forest land areas, through proper management systems and practices.
- Contribution to the production of food, water, energy and other commodities by effectively coordinating the interaction between forestry and farming systems.
- Meeting long term needs of Bhutanese people for wood and other forest products by placing all country's production forest resources under sustainable management.
- Contribution to the growth of national and local economies, including exploitation of export opportunities, through fully developed forest based industries, and to contribute to balanced human resources development, through training and creation of employment opportunities.

ORGANIZATION OF THE FORESTRY SERVICES DIVISION

The Forestry Services Division is headed by an officer of the rank of Joint Secretary. At the Dzongkhag level there are territorial divisional forest officers, who are responsible for carrying out all the developmental activities related to the forestry sub-sector. To assist the Joint Secretary in technical matters, there are four sections at the headquarters, viz; (i) Forest Resources Development Section (ii) Nature Conservation Section (iii) Social Forestry And Extension Section (iv) Forest Protection And Land Use Section.

There is one autonomous corporation called the Forestry Development Corporation, (FDC) which deals with all timber harvesting, roads building and marketing aspects. However, all harvesting of the timber, is guided by the forest management plans prepared by Forest Resources Development Section.

The territorial divisional forest officers are in the overall charge of all the implementation aspects of forestry activities in the Dzongkhags.

State of Forestry in Bhutan

All the land in Bhutan, which are not explicitly registered as private land, have been declared to be government reserved forests. The natural, ecological and climatic conditions of Bhutan favours the forests as the dominant form of land use. Due to both cultural factors and physical remoteness, Bhutan has retained much of the natural vegetation, hence has a relatively intact natural forest estate. Together with a low population base, these factors have kept forest exploitation to a minimum, a condition greatly in Bhutan's favour for moving towards sustainable use of natural resources.

Forest Area

The total land area of Bhutan is 4.024 million hectares (MPFD, 1991). The total forest area of the country is estimated at 2.9 million ha. (LUPP, 1995). From the information compiled by LUPP 1995, the forest land base, Dzongkhag-wise, is given in Table 1.

Dzongkhags	Area (ha).	Area (%)
Thimphu	108398	4
Paro	83787	3
Haa	134447	5
Chukha	156605	5
Samtse	127910	4
Punakha	87112	3
Gasa	144872	5
Wangduphodrang	298072	10
Tsirang	48658	2
Dagana	114108	4
Bumthang	181135	6
Tongsa	158249	5
Shemgang	184431	6
Sarpang	190651	7
Lhuntse	217350	7
Mongar	172258	6
Trashigang	180272	6
Trashiyangtse	110095	4
Pema Gatshel	27750	1
Samdrupjongkhar	178362	6
Total	2904522	100

TABLE 1. Distribution of forest area by Dzongkhags.

Forest Types

The major forests types are broadleaf 34.3% and conifer, 26.5% of the total land base (LUPP, 1995). Table 2 gives a detail picture of the forest types of the country.

Forest Types	Area (ha.)	Area (%)
Fir	3453	8.6
Mixed Conifer	4868	12.1
Blue Pine	1286	3.2
Chir Pine	1009	2.5
Broadleaved + Conifer	1358	3.4
Broadleaved forest	13749	34.3
Conifer plantation	20	0.1
Broadleaf plantation	44	0.1
Scrub forest	3258	8.1
Total Forest	29045	72.4

TABLE 2. Area of different forest types in Bhutan

Forest Management Planning

Production forests

The Forestry Services Division (FSD) has established a strong policy on managing the forest resources for the protection of environment. Forest resources utilization is secondary and export is allowed only after meeting the local needs of the country. Harvesting timber, on an ad-hoc basis is strictly prohibited in Bhutan. All the harvesting operations should be supported by forest management plans. The Forest Resources Development Section (FRDS) is mandated to prepare the forest management plans in the country. With the help of reconnaissance survey, the management units are identified. Generally, the size of the management unit ranges from about 10,000 to 20,000 ha. The management unit boundaries are normally topographic features like ridges, rivers or permanent roads. The following activities roughly describes the minimum activities involve in preparing forest management plans for managing the production forests: defining the boundary of the management unit a topographic map of scale 1: 25 000; with the help of aerial photographs, field visits, and geographical information system(GIS), calculating and delineating the boundary, number and areas of the stands; preparing a list of all stands showing the above attributes; calculating the annual allowable cut for the management unit in term of area and volume; selecting the stands to be harvested during the planning period; mapping the stands to be treated during the ten years periods in a 1:10,000 or 1:15,000 scale map calculating the cost and benefit for the management unit Management plans, based on the forest function approach, have been tried with the technical assistance of Bhutan-German sustainable RNR Development Project (BG-SRDP). The main objective being:

- to define different environmental and social functions within the forest management units;

- to identify production forests, and protected areas, and
- to provide a tool for management planner, for balancing the different interests of nature such as nature conservation, environment protection, social uses and commercial timber production areas.

Social Forests

Background

- *1979*: The concept of Social Forestry started in Bhutan under the Royal decree. During the initial stage, social forestry was confined to distribution of cost free seedlings
- *1985*: Social Forestry made its way into schools with the objective of "instilling love and care among school children towards trees and nature". Social forestry day was launched to commemorate the 2nd June, the Coronation Day of His Majesty the King. Since the schools and educational institutions have been observing Social forestry day with planting of trees around their campus and observing rituals for the long life of His Majesty the King.
- *1988*: The Department of Forestry and FAO collaborated to review the past activities carried out under social forestry and prepared a document. The following four models of the Social forestry were identified:

Private forestry

The model envisages the mobilization of individual action of the farmers to grow multipurpose trees within their own private land and the trees are registered in their name. This program is operational in the field.

Community forestry

This model calls for the establishment of forests by the local communities in the degraded areas presently designated as national forests. This program is also presently operational in the field.

The constraints were observed in the implementation of the community forestry activities. Communities should also be given the best forests for the protection, management and utilization. Too many steps were involved to express interest and register community forest. Tree planting conflicts with the agricultural activities.

Community Protected forestry

This model envisage handing over of the existing forests for the protection and management by the local communities who are presently using them.

If only part of the villagers were represented in the management of the forest, then during the implementation potential problems could be encountered. The traditional forest user groups as well as the forest use pattern need to be studied first.

The best piece of forest need to be handed over to the community(ies) as against the degraded forest only.

Procedures need to simplified.

- (iv) User groups should have freedom to use the proceeds from the community protected forests.
- The rules should be made simpler to the extent possible that the Department of Forestry could monitor and avoid confrontation with the communities

Lease forestry

This model envisage leasing of the degraded national forests land to an individual or a group of farmers or to forest based industries for a fixed period of time primarily for the production of tree-fodder, fuelwood, forest-based industrial raw materials, medicinal plants, and other non wood forest products.

- *1990*: Interim rules to support different Social Forestry models were formulated. These rules are presently undergoing few amendments to make them consistent with the National Forest Policy and the Forest Act.
- *1993*: These rules were reviewed to accommodate more changes based on pilot field testing. After thorough discussion, only two models were adopted. The community protected forest and community forest were merged and named community forest, the lease forest was removed. Therefore, finally (I) community forestry and private forestry were retained.
- *1995*: The new Forest and Nature Conservation Act was passed by the National Assembly of Bhutan. The community and the private forestry derive its legal status from the 1995 Forest and Nature Conservation Act.

The Social Forestry rules were further reviewed based on the Act and is under consideration by the Royal Government for its implementation.

Protected Area

National Parks and Sanctuaries

About 26% of the geographical area of the country is under protected area management systems. There are four National Parks: (i) Royal Manas National Park (ii) Jigmi Dorji National Park (iii) Black Mountain National Park (iv) Thrumsingla National Park.

The conservation management plans for Royal Manas National Park and Jigmi Dorji National Park have already been prepared and are under implementation. The management plan for Black Mountain National Park is under preparation with the assistance from WWF-Bhutan.

Besides the above-mentioned National Parks, there are four sanctuaries, (i) Sakten wildlife sanctuary (ii) Bomdling wildlife sanctuary (iii) Phibsoo wildlife sanctuary and (iv) Khaling wildlife sanctuary.

There are Nature Reserves scattered in the country for the conservation of some specific species. They are viz; (i) Toorsa Strict Nature Reserve (ii) Phobjikha Nature Reserve (iii) Gyetsha Nature Reserve and Doga Nature Reserve.

Biodiversity Survey

Bhutan is very rich in biodiversity. It has been declared as one of the global biological hot-spots. There are about 200 species of mammals, over 700 species of birds and about 5000 species of vascular plants.

Implementation of the management plans

In Production Forest

The success of the forest management plan and sustainable development depends on the effective implementation of the plan. The Divisional Forest Officer, (Territorial) Division is the overall responsible officer for the implementation of this management plan. The following activities are given due importance during the course of the implementation of the plans.

Operational plan:

The annual operational plans are prepared on time by the territorial Divisional Forest Officers in collaboration with the Forestry Development Corporation (FDC). The activities like planning, allocation of havest areas for both local and commercial uses, operational inventory design, map preparation, road alignment, plotting the data and computation of the earth work, cable crane line survey, plotting the data and preparation of maps, and for any other prescriptions contained in the plan are indicated in the Operational Plan.

Timber allotment:

The Operational Plan also contains the detail on the allotment of timber to various user groups. As far as possible, the allotments are made separately for rural and other uses. The area to be harvested or to be harvested in near future are also shown in the maps.

Road building:

For good silvicultural management of the forest, access is very important. The road construction plan is therefore clearly shown on the Operational plan with its physical targets and financial outlays.

Tree marking:

The Divisional Forest Officer entrusts the tree marking responsibility to a responsible officer. As far as possible it is done by a trained Forest Ranger.

Harvest and transport

Timber harvesting is an important activity in the implementation of the management plan. The details, indicating the method of harvest, equipment to be used, and mode of transport in the forest as well as from the forest are all indicated in the operational plans.

Measurement:

The logs are graded according to their quality and stamped for further transport by the staff of the territorial division.

Grading:

The logs to be transported from the field are graded in the field. Staff from both territorial office and FDC are involved in this exercise.

Marketing:

The marketing of the surplus timber, if any, is done by the Divisional Forest Officer with the help of FDC.

Silvicultural operations:

The silvicultural operations are given highest priority. All such activities which are planned are carried out during year by the DFO.

Protection:

Protection against fire, pests and diseases are also be given high priority.

In Protected Areas:

The Conservation management plans are implemented by the Park Managers. All the provisions contained in the management plans are implemented in close collaboration with the Dzongkhag officials, and the local people.

In Community Forest:

Community forest management plans are implemented by Users' Group. The Dzongkhag Forestry Extension Officer back-stops the communities in the implementation activities.

Industrial Plantation:

The implementation responsibility of this management plan is with the authorities of the concerned industry. The concerned (territorial) Divisional Forest Officer shall be responsible for overseeing and supervising the implementation activities. The operational plan shall be prepared by the lessee and submitted to FSD through the DFO territorial division.

Management committee

National level Management Committee

This committee is responsible to oversee and advise the implementation of the plans by the divisional level management committee. The Head, Forestry Services Division is the Chairperson of this Committee. The member shall be decided by the Head.

Divisional level Management Committee

This committee is responsible to advise the local territorial DFO on the implementation of the management plan. The chairperson of this committee is the territorial DFO.

Monitoring

The DFO in the Dzongkhag is the chief monitor of all the implementation operations. The main items monitored are the annual cut, harvesting operations, road construction and maintenance, regeneration and the environment impact. The DFO is required to submit the monitoring report annually to the head, Forestry Services Division.

Evaluation

The implementation activities will be subject to evaluation by a team appointed by the Head, Forestry Services Division. The composition of the evaluation team are normally decided by the Head of Forestry Services Division. As a normal practice there will be two evaluations of the plan implementation:

First: At the end of third year

Second: At the end of tenth year

For overseeing the implementation of the management plans, two tier management committees have been established. They are (1) National Level Management Committee and (2) Divisional Level Management Committee.

Forestry Research In Bhutan

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ABSTRACT

Scientific forest management in Bhutan started in the sixties of this century. At that time research activities rarely took place. Forestry Research was institutionalized in 1987 when the Forest Research Division FRD was created. The paper aims to give an overview of the forest research strategy and research organization in Bhutan.

In 1993 a new research strategy was implemented when forestry research was integrated into the Bhutanese Renewable Natural Research (RNR) consisting of (1) forestry, (2) field crops, (3) horticulture, and (4) livestock research. Four RNR-Research Centers (RNR-RC) were created each of them coordinating one of the four research programs. RNR-RC Yusipang is responsible for forestry research. The forestry research program aims to improve management strategies and techniques to optimize sustainable use of forest resources. At present emphasis is put on three fields of research: (1) Biology and Ecology, (2) Silviculture, and (3) Post-Harvest Management. The main subprograms cover problems of regeneration dynamics, growth studies, vegetation investigations, conifer group felling systems etc. To implement the research strategy international research cooperation has to be improved establishing institutional frameworks.

KEYWORDS-- *forestry research, renewable natural resources, ecological research, silvicultural research.*

INTRODUCTION

Forestry research in Bhutan started in the late 1970's but it was mainly conceived as a support to various forestry development projects. Forest research was institutionalized in 1987, with the creation of Forest Research Division (FRD) based in Taba (Thimphu) under the Forest Services Division (FSD) the then Forest Department (FD) and had the following objectives:

- To conduct basic to more applied research to support better ways of forest management and forest utilization.
- To coordinate forest research nationally carried out by various organizations.

Due to the limited number of forestry researchers (Table 1), activities were confined to conifer and broad-leaf forest management with the Forest Services Division(FSD) as the main client. The UNDP/FAO project supported FRD from 1988-92. In 1990, a regional forestry research station was created under the SDC/Helvetas supported Integrated Forestry Development Project in Bumthang (Central Bhutan) and it concentrated on silvicultural research in conifer forests. During 1993, with the re-organization of Ministry of Agriculture (MoA), forestry research joined the Research, Extension & Irrigation Division (REID) to form one of the four national Renewable Natural Resource (RNR) research programs (the other three being Field Crop, Orchard and Livestock research programs).

Category	**1989**	**1990**	**1991**
Researcher[a]	1	2	2
Research Assistant[b]	2	4	4
Technicians[c]	4	7	6
Librarians	0	1	1
Total	**8**	**14**	**13**

TABLE 1. **Staff Development for Forest Research Division 1989-91[d]**

a. Forest graduate
b. Dipl. in General Forestry
c. Forest beats/guards
d. Source: Ijssel & Norbu, 1991.

RENEWABLE NATURAL RESOURCE RESEARCH CENTRE (RNR-RC)

In the RNR concept, research of all four sectors (forestry, field crop, horticulture and livestock) in the MoA are integrated and undertaken at one of the four regional Renewable Natural

Resource Research Centers (RNR-RC) located across the country. The four regional RNR-RCs are:

- *RNR-RC, Yusipang* Thimphu, Paro, Ha, Chukha & Samtse in the western region;
- *NR-RC, Bajo* Gasa, Punakha,Wangdi , Tsirang in the west- central region;
- *RNR-RC, Jakar* Bumthang, Trongsa, Zhemgang and Sarpang in the east-central region;
- *RNR-RC, Khangma* Tashigang, Monggar, Lhuntsi, Tashi Yangtsi, Pema Gatsel and S/Jongkhar in the eastern region.

Besides carrying out RNR research specific to regional needs , each RNR-RC is responsible for coordinating one of the four national RNR research programs nationwide. Accordingly, RNR-RC, Yusipang is responsible for coordinating forestry research program; RNR-RC, Bajo for field crop research program; RNR-RC Jakar for Livestock research program; and RNR-RC, Khangma for horticulture research program.

OBJECTIVES OF FORESTRY RESEARCH

In the light of forestry research integration with the other sectional research, the objectives of forestry research are redefined on the basis of the development policies and strategies identified in the Forestry Sub-Sector Development Policy and Strategy (MoA, 1995). The key points identified in the Forestry Sub-Sector Development Policy and Strategy relevant to forestry research are as follows:

- to maintain and enhance the conservation, protection and support role of forests through integration with the RNR sector;
- to put more forest areas under sustainable management in order to meet increasing demands for forest produce;

- to create conducive conditions for the protection and efficient use of forest resources through legislative measures such as Forest Act, Timber Pricing Policy etc.;
- to encourage peoples participation in forest management and create awareness through a strong extension service;

Research in forestry must contribute to the above strategy. Accordingly, the immediate goals of forestry research are in the (Draft) Research Strategies and Plans for the National Research Programs and the RNR-Regional Centres for the 8th Five Year Plan (1995) as follows :

- ***to identify, adapt or develop appropriate technologies or management strategies in forest management and production for optimizing the integrated production processes within the entire RNR system, promoting the sustainable management of forest resources and the contribution of forests to resource and environmental protection and to increasing production and outputs of marketable/consumable forest products.***

The strategy for the Forest Research Program (FRP) is to draw as far as possible on relevant information and technology from outside Bhutan. The FRP will focus its research and experimental programs on areas where research outputs cannot not be drawn from elsewhere. Effective linkages with forestry research elsewhere will be set up and maintained. Also, research in forestry has an important role in relation to the development of forestry policy and legislation (e.g. in relation to example for livestock/forest interactions) The linkage, and thus involvement, of forestry research with broader policy issues should also be noted with respect to environmental issues. The monitoring of the state of the nations natural forests on effects of management practices and methods of timber and other forest produce extraction on the state of the national forests are all key RNR policy areas to which forestry research must contribute.

Forestry Research Program Structure

The scope of forestry research is limited to silviculture and management and this needs to be expanded. The new Forestry Research Program is divided into three broad disciplinary sub-programs: Biology and Ecology, Silviculture & Management and Post-harvest Management (Table 2). This division reflects clear research problem areas requiring different disciplinary inputs and clear separable outputs although they are inter-linked. Studies relating to developing basic knowledge on forests and forestry systems are grouped under Ecology and Biology. Those investigations relating to technologies for improving forest management are situated under the Silviculture & Management sub-program and investigations related to utilization, storage, processing and marketing of forest products have been placed with the Post-harvest management sub-program.

FORESTRY RESEARCH PROJECT STRUCTURE

Founded on the observations and experiences of forestry researchers the following broad research needs are identified:

- Forest vegetation dynamics in conifer and broadleaf forest.
- Appropriate silvicultural systems for conifer and broadleaf forest.
- Cultural practices, cleaning, weeding and thinning for enhancing regeneration development and wood quality.
- Forest plantation research- nursery and out planting practices
- Tree improvement studies for conifer and broadleaf.
- Integration of tree growing in the farming system through agro-forestry.
- Policy and social research on grazing, uncontrolled burning and resin tapping.
- Indigenous forest management and non-timber forest products
- Post harvest studies for timber and non-timber forest produce.

To address the above issues, four national projects are proposed in Conifer, Broadleaf, Non-wood products and Social Forestry and these will be represented in each Subprogram (Table 2). Extensive forest areas, both conifer and broadleaf forests, are managed for timber production. Appropriate technology (e.g. silvicultural practices) to improve production has to be found. Management studies

Sub-program	Biology & Ecology	Silviculture & Management	Post-harvest management
Project	Conifer	Conifer	Conifer
Project 2	Broadleaf	Broadleaf	Broadleaf
Project 3	Non-wood products	Non-wood products	Non-wood products
Project 4	Social forestry	Social forestry	Social forestry

TABLE 2. Proposed structure for the Foresty Research Program and Project.

for conifer and broadleaf are of equal important. Management and utilization of non-wood and wood forest products are gaining importance and studies have to be initiated for important non-wood forest produce. Recognizing that Social Forestry will gain momentum in future, research of social forestry systems is will be initiated.

REGIONAL DISTRIBUTION OF THE RESEARCH PROGRAM / PROJECTS

Research needs are enormous and diverse from one region to another. In order to increase the efficiency of the research system considering the limited resources, research projects will be prioritized on the basis of regional needs to make them region specific and also avoid duplication of the activities. In view of this, conifer research will be centered in east-central region (RNR-RC Jakar); broadleaf research in the eastern (RNR-RC Khangma) and western (RNR-RC Yusipang) regions; non-timber forest product and social forestry research in eastern (RNR-RC Khangma) and west-central (RNR-RC Bajo) regions.

In sub-program or discipline-wise, Biology and Ecology, and Silviculture and Management should be spread across all the regional centers but only some activities in the west-central region. Post-harvest study on timber will be confined to the western region in view of many wood-based industries located there and post-harvest studies on non-timber produce (NFTP) will be initiated in eastern and west-central regions.

OVERVIEW OF PAST/ ONGOING RESEARCH

Biology & Ecology

Lack of basic information on different types of forest has been the constraint to successful management of forests. A number of studies have been undertaken or are in progress in the areas of phenology, seed fall, genetics, growth and regeneration for conifer and broadleaf forests. Little information has been generated leading to understanding of some bio-ecological phenomena of Bhutanese forests. Knowledge on regeneration dynamics for a few species - hemlock, spruce and fir in conifer forest and Lauraceae & Symplocus species in upland broadleaf - has been improved through regeneration studies. Tree growth studies have led to development of local volume tables for main conifer species and understanding of growth pattern for Nyssa javanica, Symplocus lucida, Symplocus glomerata and Alcimandra cathcarthii, Pinus wallichiana and Cupressus himalica. Identification of native flora which is a prerequisite for embarking on conservation program is being facilitated through maintenance of herbarium which now has over 10,000 collection of native plants.

Silviculture & Management

The development of appropriate technology on the rational use of forest resources for sustainable production of goods and services is the main thrust of the FRP program. The research activities have concentrated on investigating the adaptation of appropriate silvicultural systems in natural forests and, in improving plantation forestry.

Many of the studies initiated are long-term and only intermediate results have been reported so far. Studies on silvicultural system in East Central (Bumthang) and West (Thimphu, Paro and Ha) show Group Felling System promising for management of conifers. All the Forest Management Units (FMU) in conifers, mainly mixed conifers, are now subjected to Group Felling system. Thinning studies to improve the stands are on-going in blue pine forests of Bumthang and Thimphu. Studies on silvo-pastoral system in blue pine forest in Bumthang and in fir forest in Ura, and grazing studies in the East (Korilla) and West (Gedu) are some of the initiatives made on the subjects dealing with forest/livestock interfaces. Some areas of the broadleaf forest in the southern part of the country are leased to industries which are clear-felled and planted with fast growing tree species as an industrial plantation program. Establishment of species/provenance trials and seed production areas have initiated to back up these industrial plantations.

Post harvest management

Although post-harvest management to reduce wastage of forest produce and to increase the value-added of harvested timber for export is important, no studies, except on shingle making for fir in Ura under IFMP project, have been conducted due to resource constraints.

FORESTRY RESEARCH PROGRAM MANAGEMENT.

An annual coordination meeting of the FRP is held to review the annual national forestry program and to plan for the activities in the coming year. All the relevant clients and stakeholders attend the meeting. The FRP coordinator from RNR-RC, Yusipang make visits to each of the RNR-RCs to review the progress on implementation of the agreed activities under the FRP. Similarly, an annual regional planning meeting is held to review the annual regional RNR research (forestry, livestock, field crop and horticulture) and plan the activities for the coming year for each RNR-RC. All potential clients in the region attend the meeting.

INTERNATIONAL COOPERATION AND SUPPORT TO FRP

FRP is a small and growing institution. FRP is the member of two regional projects -the Forest Research Support Program for Asia & Pacific (FORSPA), and Forest Tree Improvement Project (FORTIP). Through these two projects, FRP has been twinned with many national forestry institutions and other international forestry-related institutions in the region. Although FRP has access to some of IUFRO's information and researchers at times attend IUFRO-organized seminars, FRP is not the member of IUFRO. As the strategy of FRP is to draw upon relevant information and technology from outside Bhutan, it looks forward to collaborating with the fellow foresters and researchers across the globe in the management and conservation of forest resources.

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Part 3

Road Planning and Engineering

Evaluation of forest road networks - a review of different methods

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ABSTRACT

The opening up of forests in Austria enables the population to gain access to previously difficult to reach forest areas. The prime function of a production forest cannot solely be found in the economic production of the raw material wood, but is often related to completely different spheres of influence, such as its use as recreational area, as a water reservoir or as protection of settlements from mudflows and avalanches.

Planning forest networks in complex ecosystems requires the consideration of a wide variety of interests, which have to be balanced against each other. A diverse spectrum of criteria to assess the individual road network alternatives should lead to optimal solutions which meet the demands of the population on the forest as a natural ecosystem while also maintaining an intact ecological system.

In the course of this assessment numerous questions arise ranging from the definition used for the different assessment criteria and their corresponding grading, to those dealing with the monitoring and evaluation of elusive qualitative factors and their conversion into some form of quantitative yardstick.

A number of authors have attempted to devise models for the assessment of different forest road variants. The demand for an operational, manageable and comprehensible decision-making aid is stronger than ever before.

Building on this experience, the following summarisation of methods for evaluating forest roading variations is dealt with from a critical viewpoint. Future prospects and possibilities for the further development of such process models are then discussed.

KEYWORDS--*Opening up planning, assessment of road networks, GIS-supported planning, information sources, environmental impacts*

INTRODUCTION

Most of the Austrian alpine forests have comprehensive road networks already in place. The current difficulty is providing road networks for the protection forests on very steep slopes. These regions have remained unroaded because of the difficulty of the terrain, however the provision of a road network for these protection forests is becoming urgent to stabilise these forests.

The construction of forest roads have extensive influence on the ecosystem of the forest and these days attract a lot of public interest. The legal requirements for the planning and construction of forestry roads (Austrian Forest Law, Nature Laws of The Districts, Water Rights) make a transparent and operational decision support system for the finding of optimal roading networks more relevant than ever before. The functions of the forest are defined by the Austrian forest law of 1975: (1) use (2) protection (3) recovery and (4) well-being. Further, the law requires the assessment and evaluation of the whole forest with regards to these criteria in the form of a forest development plan. This plan forms the basis for the planning of structural measures for forest development. The areas of concern with poorly developed roading networks are primarily located where the protection function is the most important, and not the economical use.

The subsidies for forest roading projects from national and EU money provide for approximately 40% of the costs. The consideration of the public interest in the planning process is an important aspect and justifiable since considerable governmental subsidies are provided. A transparent evaluation of the network options should help to determine the most appropriate solution.

Various methods of evaluating road networks are available from the literature. An overview of these methods is presented. A look into the future regarding the further development and incorporation of these procedures into the environmental audits is presented. Roading networks, especially in sensitive ecosystems, where the use function is less important, requires a careful planning process.

CRITERIA AND EVALUATION METHODS

Various roading network possibilities are evaluated according to their (1) technical suitability, (2) economical suitability (3) their environmental aspects and (4) their social integrity (Heinimann, 1996). These methods usually distinguish themselves into (i) qualitative and (ii) quantitative criteria (Wolf, 1994; Gundermann, 1978; Dürrstein, 1996). The quantitative criteria are those that can be expressed monetarily in the form of a cost-benefit analyses. The qualitative criteria are those that are difficult to quantify. While the cost-benefit analyses is easy to carry out, the evaluation of qualitative criteria presents difficult to answer questions. The evaluation methods are fundamentally different and these are presented, whereby important characteristics are given special attention.

Heinimann (1996) discusses criteria and indicators of environmental and social value pointing out that technical and economical evaluations are already handled extensively in forestry. The four phase evaluation model is divided into the following sections:

- Identification of potential effects (risk analyses; causes; effects)
- Identification of significant effects (scaling problems, interval scales)
- Bringing together the significant effects (‘ranking’)
- Further recording of the development of realistic projects for model development (feedback, ‘plan, do and check’)

For the evaluation of various environmental factors, an overview of criteria is presented with the associated risks and measurable parameters that allow a quantitative evaluation. This is a very valuable starting point particularly when implementing a geographical information system (GIS). The importance of these factors and indicators for determining the effects exists in a standardised set of indicators whose consequences allow the comparison of various projects.

Gundermann (1978) developed a combined cost-benefit-efficiency analyses and attempted to combine the strengths of both procedures, namely the cost-benefit analyses for the monetary assessable, quantitative criteria and the efficiency analyses for the qualitative criteria. The fundamental idea is that first the individual variations are evaluated according to their cost-benefit analyses and then incorporated into the factor analyses whereby population effects, ecology, and protection forest care are considered.

The choice of the criteria and the weighting for the ‘partial benefit values’ is completed using a delphi procedure on the basis of questioning 90 experts from different interest groups.

The chosen criteria are coupled and weighted and each partial benefit value determined. Finally the total benefit value for a particular variation is calculated (Tab. 1). The signs before the step weights are important. The positive criteria have a positive effect, that means the partial bene-

Criteria	sign	weighting G	fulfil–ment E -2 to +2	partial benfit value TN
net benefit	+	469	+1	+ 469
kind and frequency of use	+	46	-1	- 46
social-hygienic effects	-	25	-1	+ 25
aesthetic-emotional effects	+	30	+2	+ 60
...	...	...	...	...
...	...	...	...	...
total benefit value		1000		+ 650

TABLE 1. **Combining the weighting and fulfillment grades into partial use values (Gundermann, 1978).**

fit value is added to the total. Alternatives that are neither rated positive or negative become a ‘fulfilment’ grade of 0 and therefore the partial benefit value is 0.

Without commenting on the chosen criteria, the weighting of the net benefit value makes up 47% of the total, which appears to be very high. With the transformation of the net benefit value into a partial benefit value using the high weighting, means that the previously mentioned criteria are underrepresented (weighting of 1.4 to max. 6.4 %). Also the scaling of the fulfilment grades (-2 to +2) for the individual criteria seems difficult.

Dürrstein (1996) presents a method in the form of a cost-effectiveness analyses. An considerable difference to the previously mentioned methods is the isolated consideration of the costs. The costs are not included in the evaluation process and are handled separately until the deciding process.

The main steps in the process are as follows:

1. preliminary work
- definition of needs
- proposal of roading alternatives
- selection of the effects and risks.
2. Analyses
- partial benefit values for ecological, technical and socio-economic values
- total benefit values for the various alternatives
- calculation of cost benefit factors
3. Ranking of opening up alternatives

The goal is to find an alternative that,

- fulfils the road network requirements,
- minimises the risks,
- and achieves the desired effect.

The division in "needs, risks, effects" makes it possible to find an alternative that is balanced in all three categories. The active participation of varied interested parties (farmers, forest owners, private environmental organisations, fishing interests) during the decision making process is an important part of the procedure.

Wolf (1994) chooses according to Gundermann (1978) a division between qualitative and quantitative criteria set and orders each a maximum of 50 points to each. Each road network design can then reach a maximum value of 100 points (Tab. 2).

Assessment criteria	max. points
benefit-cost difference	50
Assessment criteria	**max. points**
Average bend and road distance	10
steep terrain	5
bends in steep terrain	4
Critical geological areas	4
road in rock	4
Biotopes to be protected	6
lakes and rivers near the road	5
visual impacts of the road	5
Recreation function	5
Protection- and welfare function	2
Sum	50
Total	**100**

TABLE 2. **Points distribution for the forest roading alternatives, after Wolf (1994)**

The ordering of points according to quantitative criteria depends on the net benefit values and follows according to a not further defined ‘exponential function’ to ensure that a negative cost-benefit analyses is not over valued. Also here the ecological and socio-economic factors seem under represented or fail completely. For example, the protection and well-being functions are named with a point value of 0 or 2 depending on the importance of the network alternative. In comparison to the 50 points available for this area these 2 points seems to be very low. A clear separation for the effects and for the measurable indicators is not presented.

EVALUATION OF ALTERNATIVES AS A PART OF THE PERMIT PROCESS

An environmental impact assessment required by the governmental authorities is commonly done for larger projects that can seriously impact the environment (for example hydro-electric power dams). Forest roading projects in mountainous areas also make a significant impact from an ecological point of view. This means that roading projects should also be required to undergo an environmental audit. The increasing public interest in forestry issues and the maintenance of the sustainability of our forests is reason enough for a fundamental examination of the roading measures. Improper forest roading projects, be it through poor planning or construction techniques can have extensive negative impacts and can be the reason for catastrophic landslides (Langer, 1975).

The ‘general roading plan’ as an integrated design project gains in significance in recent years. Every intensive plan should have been proceeded by a general plan. It is often personal interests such as those from the forest owner, that presents the greatest hurdle to an efficient and ecologically acceptable solution.

DATA REQUIREMENTS FOR GIS SUPPORTED ROAD NETWORK PLANNING

In Austria there is a comprehensive digital data set available with regard to basic mapping information. In the following summary, the various information levels that form the basis of GIS-based planning are presented (Fig. 1).

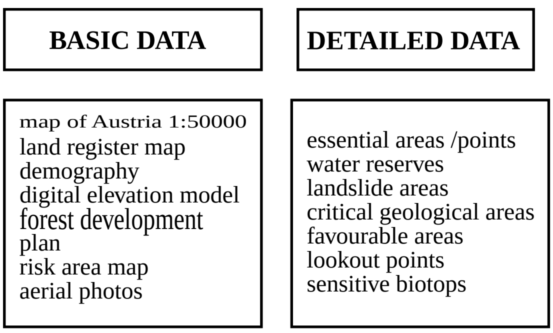

FIGURE 1. **Database requirements for the GIS use in alternative evaluation.**

While the base data is readily called up and can be used for the basic mapping in the filed, the collection of data in the field and the transformation into GIS is associated with a lot of work. The exact coordinate location of objects in the forest still presents a problem. Developments in location and navigation in the form of Global Positioning Systems (GPS) are working towards methods that allow accurate position determination in a covered forest. With enough information about the area of interest it should become possible to provide a SDSS (Spatial Decision Support System) to analyse the alternatives using GIS.

CONCLUSIONS

Various methods for the evaluation of roading network designs try to provide a comprehensive overview of the environmental influences on the forest. Key questions remain the selection of criteria and their weighting, and the indicators that should lead to a quantitative evaluation. The analyses of the published evaluation procedures leads to the following conclusion:

- The isolated consideration of the net benefit value of a road network option from ecological, socio-economical effects appear to be an important point. This is especially so in critical geographical areas where cost considerations should not override the decision making process.
- The involvement of varied interest groups in the decision making process lead to a greater acceptance.
- It appears important to make post project controls so that information can be gathered to provide feedback and improve the models.
- The incorporation of evaluations of alternatives into the public permit procedures is desirable from a public point of view since approximately 40% of the total costs are obtained from subsidies.
- Further studies should evaluate the implementation possibilities of geographical information systems in the planning process, in the form of a decision support system.
- An extensive range of fundamental base data already exists in digital form. The collection and evaluation of field data in GIS, eventually with the use of global positioning systems (GPS) could bring further rationalisations.

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Environmentally Friendly Road Building In Bhutan The Forestry Development Corporation Experience

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ABSTRACT

In Bhutan mountainous terrain dominates and is very rugged due to the geology. Accessibility of forest land therefore is a precondition for the management and use of forest resources. The paper gives a survey of the development and the present status of forest road engineering.

Until 1970 construction of forest roads was done by harvesting contractors. This lead to poor road standards with poor alignment, high gradients and insufficient drainage. By the end of the seventies' efforts were made to improve the situation through training of specialists in road planning and construction. 1989 the Forest Development Corporation FDC became responsible for all commercial harvesting operations including road construction. Under the responsibility of FDC more than 300 kilometers of forest roads were constructed. Because of the dominating steep terrain conditions the main transportation concept is based on forest roads combined with long distance cable cranes (1500 meters) resulting in road densities around 10 meters per hectare. Technical specifications were fixed by minimal standards such as maximum road gradient (12%), maximal road width (5 m), etc. Cost figures drawn from past experience are available for earth work as well as for pavement, drainage and retaining structures.

KEYWORDS-- *Road planning, road construction, road specifications, cost figures.*

INTRODUCTION

The entire kingdom of Bhutan except a small strip in the south falls in the eastern Himalaya. The total geographical area of Bhutan is approximately 46,500 sq. kilometres, roughly 150 km north- south and 300 km east-west. The map of Bhutan and neighbouring countries are illustrated in figure 1.

FIGURE 1. **Map of Bhutan and its neighbour countries**

The land rises from an elevation of about 160 metres above sea level in the south to more than 7,550 metres in the north. All the rivers flow towards the south. The terrain is very rugged and mountainous especially the riverbeds which are deep gorges.

In the central belt, temperate vegetation consists of both broadleaf with thick under growth and conifers. In the southern belt broadleaf species exist with very thick under growth.

The rainfall, in particular, can differ within relatively short distances due to rain shadow effects. The annual rainfall is concentrated in the monsoon season.

Estimated annual rainfall data are presented in table 1.

Region	Annual precipitation
Southern border areas	3000 - 5000 mm
Southern foothill	1200 - 2000 mm
Inner Central valleys	500 - 1000 mm
Above 4000 m elevation	Less than 500 mm

TABLE 1. **Annual Precipitation**

Modern scientific forest harvesting in Bhutan started only in the year 1975. Forest harvesting was nationalized towards the later part of 1970’s. Until then forest harvesting operations were done by the contractors including road construction and timber marketing. The condition of roads were very bad with high gradient, sharp bends and almost without paving. The sole purpose was to extract the timber with minimum cost.

Though the forest harvesting was nationalized there was acute shortage of equipment and trained manpower especially in road building. In 1979, some field officers and staff were trained in forest road planning and construction in the country with the help of an FAO project. Some road building equipment was also purchased. In 1989, commercial forest harvesting, road building, plantation work including timber marketing activities were separated from the Department of Forestry and became an autonomous corporation with the name Bhutan Logging Corporation which was renamed as the Forestry Development Corporation (FDC) in 1996. Even today we are still lacking technical know how and appropriate road building equipment. But, we hope to over come from these problems in the near future.

PRESENT STATUS

So far we have constructed about 300 km of forest roads including seasonal roads in various Forest Management Units.

Planning and Construction

The road requirement is according to the distance coverage of the cable-crane. We are using 1,500 m range skyline cranes. Careful selection is done to put the road in the most desired place avoiding slide/steep/fragile areas. In some cases, villagers also get benefit of the road, because the road goes near the villages. But it would be difficult for the autonomous corporation to provide road to the villagers in every management unit unless some organisation subsidizes the costs.

Technical Specifications

The *road gradients* followed are:

Maximum: 10 - 12 % - In some places we have to use the old road constructed by the private contractors and there are gradients more than 12%.

Minimum: 3% - If less than 3% gradient there will be a problem with proper drainage.

Average: 6 - 8%

Right-of-way clearing: 10 - 15 m - Usually it is 10 m but in thick and moist forest it is almost up to 15 m to keep the road surface dry.

Formation width: 4 - 6 m - In average, it is about 5 m. In steep, rocky area it is 4 m and in gentle slope and in curves it is up to 6 m.

Side drain and Shoulder: 0.5 - 1.0 m - In rocky areas it is less and in soil, it is up to 1 m. During road maintenance, drain cleaning is done by machine.

Edging: 15 cm width in both sides.

Carriage way : 3.0 - 3.7 m Less in straight and more in curves.

Culverts are provided in dry/perennial streams. Walls are constructed in slide prone places. We have already started to provide surface cross drains to keep the road surface dry. We will replace the use of bulldozers with excavators.

Other Environmental Protection Works: We have already started to provide for bio-engineering works with the local species in the excavated exposed slopes. This is extensively done in Shingkhar road constructed by our sister project IFMP Ura.

COST

It is not easy to make environmentally friendly roads with low costs. But of course, there is one important aspect i.e. to reduce the road width as far as possible. Commonly, Bhutan is using TATA trucks (from India) which have relatively small body compared with other logging trucks.

The following are the cost details of road building used by the Forestry Development Corporation: Nu 36.90 = US $1.00. With the rates mentioned above, the road cost is nearly Ngultrum one million/km (or US $27,000/km).

Item	Cost (Ngultrum)	Cost (US $)
Clearing		
Right-of-way clearing: clearing of vegetation, grass, brushwood and trees up to 30 cm diameter	0.90/sq m.	0.02/sq m.
Earth work		
Earth extraction	< 29/m3	0.78/m3
Rock extraction	< 76/m3	2.05/m3
Bio-engineering works	2,500.00/km	68/km
Pavement structure		
Sub-grade preparation	< 2/sq m	0.05/sq m
Edging	< 207/m3	5.60/m3
Soling	<179/m3	4.85/m3
Sub-base course	360/m3	9.76/m3
Base course	413/m3	11.20/m3
Shoulder filling	<12/m3	0.33/m3
Surface binding	16/m3 0.45/m3	
Drainage structures		
Side drains in soil	29/m3	0.78/m3
Side drains in rock	75/m3	2.05/m3
Surface cross drain	500/each	13.55/each
Culverts/bridges	Analysis in each case	
Retaining structures		
Dry masonry	263/m3	7.13/m3
With cement plaster	<1,243/m3	33.69/m3

TABLE 2. **Road building cost**

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Aggregrate-surfaced Forest Roads – Analysis Of Vulnerability Due To Surface Erosion

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ABSTRACT

The pavement of forest roads consists of several types of structural designs. In the Swiss Alps unpaved, aggregate-surfaced roads have the biggest significance, whereas paved roads are only used in areas with intensive precipitation and traffic. Earth-roads are limited to skid roads actually having become less important. Structural safety and operational serviceability are the two design principles widely used by engineers. Traffic, frost actions, and rainfall effects are the main causes for the deterioration of road serviceability over time. Pavement design guides accumulated a large knowledge of traffic and frost effects whereas there are only limited findings explaining other causes of aggregate loss.

The study aims to analyze the influence of road gradient, cross-section grading pattern and drying up on aggregate loss. A logistic regression model makes it possible to quantify the probability of surface deterioration. Road gradient has the biggest influence on aggregate loss. Potholes are of frequent occurrence when road gradient is low. The probability of erosion gullies increases with higher road gradients whereas cambered cross-section grading significantly reduces aggregate loss. The drying up effect has a small influence when the roads are protected by tree canopy. The empirical findings are only valid for the investigated region and aggregate materials. The trends are probably similar under different conditions and the methodological approach could be used to evaluate different aggregate surfaced roads.

KEYWORDS--*aggregate-surfaced roads, deterioration processes, pavement distresses, pavement management, surface erosion.*

INTRODUCTION

In Central Europe forest road networks mainly consist of aggregate-surfaced roads, while paved and earth-roads are of secondary importance. Pavement design philosophy for low-volume roads has been based on a life-cycle approach since the establishment of design procedures as documented for instance in the AASHTO-guidelines (AASHTO, 1986). There are two main criteria that engineers have to consider in the design process: structural safety and serviceability. In pavement design, serviceability has always been the crucial component. Its decrease consists of several distresses of which erosion of road surface is the most important one (Foltz 1996, 1997; Lienert 1984). To develop adequate road construction, maintenance, and rehabilitation strategies we need to improve our knowledge about the deterioration processes (AASHTO 1986).

Investigations about road erosion used two different approaches. Empirical investigations resulted in findings that are only valuable for the underlying data. For Central European conditions the survey study of Lienert (1983) demonstrated that about two-thirds of the aggregate-surfaced roads have erosion distresses such as gullies and potholes. The US Forest Service conducted a study to investigate rut development and sediment production (Foltz 1996). A semi-empirical approach was used combining parametric physical models with field experiments. Provencher (1995) and Kennedy (1997) studied the interaction between deterioration and maintenance frequencies. Both authors concluded that considerable reduction of surface sediment can be realized with appropriate and timely road maintenance. All the studies focus on partial aspects of the deterioration process. The effect of different grading patterns, of canopy protection, and their interactions with road gradient have not been adequately analyzed.

The objective of this study was (1) to analyze empirically gully and pothole erosion of aggregate-surfaced roads, and (2) to develop a vulnerability model considering various factors of influence. Validity of the results is limited to the study area in Switzerland where data were available. In the present paper a review of pavement design and maintenance principles will be given, the study layout and data analysis will be discussed, and model analysis will result in recommendations for road management.

BACKGROUND

Types of pavement structures

A pavement structure is a combination of subbase, base course, and surface course placed on a subgrade to support traffic load and distribute it to the roadbed (AASHTO 1986). The layers have the following function (AASHTO 1986):

- ***subgrade*** - the top surface of the roadbed upon which the pavement structure is constructed. The top of the subgrade is often stabilized or compacted in-place to a specified density.
- ***subbase*** - the layer or layers of specified or selected material of designed thickness placed on a subgrade to support the base course.
- ***base course*** - the layer or layers of specified or selected material of designed thickness placed on a subbase or a subgrade to support a surface course.
- ***surface course*** - one or more layers of pavement structure designed to accommodate the traffic load, the top layer of which resists skidding, traffic abrasion, and the disintegrating effects of climate. The top layer of flexible pavements is sometimes called the „wearing course".

Figure 1 illustrates the most widely used pavement structures for the conditions of Central Europe. Earth roads are

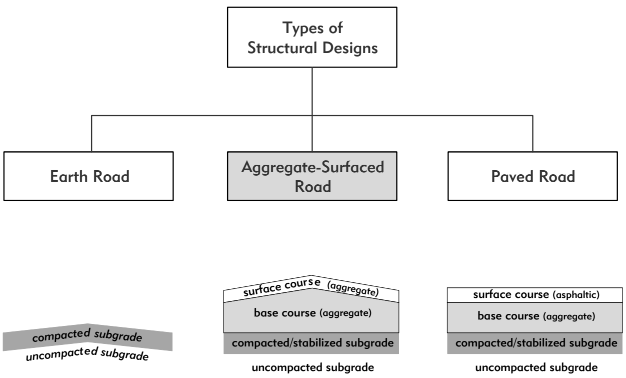

FIGURE 1. Typical types of pavement structures for forest roads in Central Europe

only applied for skid roads and are limited to soil conditions beyond a minimal soil bearing capacity. In Switzerland, aggregate-surfaced structures are dominant on forest roads. On soils with low bearing capacity the top surface of the subgrade is often stabilized with lime. The base course consists of gravel or crushed rock, and the surface course is built of crushed aggregate material causing binding effects (cohesion forces due to lime or clay components). Paved roads are applied in regions with high thunderstorm risk and frictionless aggregate materials.

Grading patterns (Figure 2) aim to control road surface drainage. Cambered and crowned patterns are the most

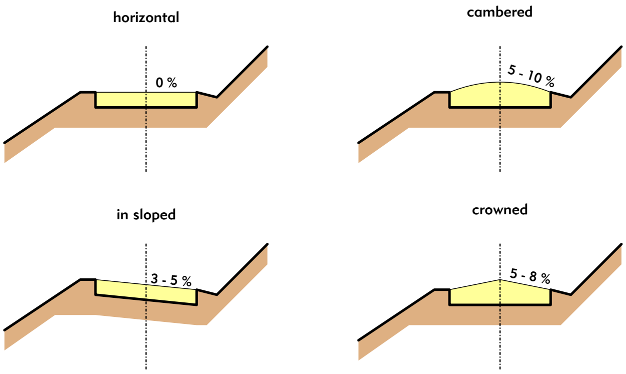

FIGURE 2. **Typical cross-section grading patterns for aggregate-surfaced roads.**

effective approaches for water removal. However, they require water control on both sides. Longitudinal flow of water along the cut slope follows ditches and uses regular spaced culverts to cross the road structure. Horizontal grading is the easiest way for construction. Rutting due to heavy traffic causes ponding water increasing the deterioration process of the road.

Principles of pavement design

Engineering design is based on two basic principles. Structural safety aims to support loads without excessive distortion of the investigated engineering structure within acceptable limits of risks. Operational serviceability has to perform user comfort functions, to guarantee durability, and to fulfill aesthetic requirements. At present, engineering standards have been adapted consequently to the „safety-serviceability“ philosophy, for example the European Standardization with its set of EUROCODES (see e.g. CEN 1995).

In Switzerland the pavement design process for forest roads uses the AASHTO-guidelines (AASHTO, 1986) which were adapted to the special conditions in the Alps (Burlet 1980). The AASHTO-procedures make it possible to determine the total thickness of the pavement structure as well as the thickness of the individual structural components. Thickness determination is a typical engineering activity aiming in modeling the physical ***behavior*** and the safety of the pavement structure. Assuring reliable performance over a whole project life cycle additionally requires the consideration of serviceability criteria. Serviceability mainly depends on user evaluation and may be derived from ***distresses*** of the road surface (see table 1). However, there is a lack of long-term time series recording serviceability of various pavement types (AASHTO 1986). There are only a few studies investigating the deterioration process of aggregate-surfaced roads. Aggregate loss, deformation of the pavement structure and disintegration of surface material have a key influence on serviceability. For Alpine conditions Lienert (1983) analyzed distresses of aggregate-surfaced and paved low volume roads. According to Foltz and Elliot (1997) the deterioration of aggregate-surfaced roads starts with rutting caused by traffic. Ruts encourage the building of erosion rills due to concentrated runoff of surface water. Their investigations show that aggregate loss is two to four times greater on rutted than on freshly graded roads. Table 1 summarizes the main problems met in the deterioration of aggregate-surfaced roads considering the systematics of Eaton et al. (1987) and Lienert (1983).

Deterioration process	Distresses
Aggregate loss	• potholes • erosion gullies • flacking off of wearing course • washboarding
Disintegration of surface material	• loose aggregate • dust
Deformation of pavement structure	• ruts (crosswise deformation) • corrugations (longitudinal deformation)
Deposition of material	• accumulation of eroded material • overgrowth of surface course (organic material)
Improper flow of water	• ponding water in the ditches • debris in the ditches • overgrowth in the ditches • erosion of ditches into shoulders

TABLE 1. **Deterioration processes on aggregate-surfaced roads. Serviceability is a criterion aggregating the various distresses to a common measure.**

Life cycle model

In the past, design alternatives have considered only those structural problems that are expected to last the entire predicted service life. Pavement management integrates (1) design, (2) construction, (3) maintenance, and (4) rehabilitation procedures using life-cycle economics for comparing the advantages of various pavement types (AASHTO 1986). Life-cycle analysis of aggregate-surfaced forest roads goes back to the US Forest Service Transportation Analysis Group TAG (Sullivan 1975) which studied the deterioration of unpaved roads. In cooperation with the Institute of Transportation and Traffic Engineering, University of California at Berkeley, it developed a life cycle strategy for forest roads covering (1) construction and maintenance cost, (2) traffic volume, (3) road serviceability, (4) vehicle operating cost, and (5) total cost flow. The basic ideas used in forest road pavement management, as presented in figure 3, date back to Sullivan (1975).

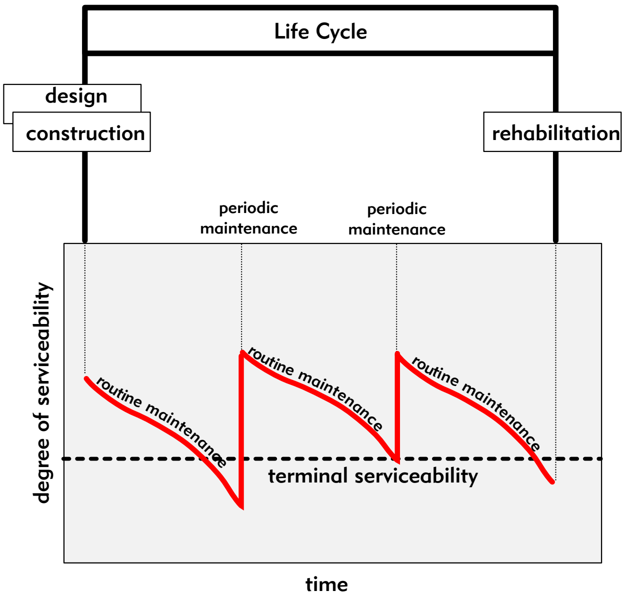

FIGURE 3. Life-cycle model of a pavement structure.

The project life cycle starts with the designing and construction activities. It then estimates the serviceability trend for specific pavement, traffic, and environmental conditions. At the time when the serviceability index falls below the terminal serviceability, periodic maintenance has to improve the road conditions. For aggregate-surfaced roads regrading rebuilds the road cross-section pattern and compacting increases abrasion resistance. At the end of the life cycle (40 to 50 years) the structural strength of the pavement decreases due to wear effects and rehabilitation activities take place. The main problem in analyzing and evaluating the life-cycle effects is finding a model that forecasts the serviceability trend reliably. As stated earlier there is a lack of knowledge in this field. Luhr and Mccullogh (1983) present a case study that compares serviceability trends between three pavement types (aggregate-surfaced, surface treatment, asphalt surface course). Their investigation shows a cycle for the periodic maintenance of about six years for the aggregate-surfaced type, of about twelve years for the surface treatment structure and more than twenty years for the asphalt surface type. The Forest Engineering Research Institute of Canada (FERIC) has been conducting a study that aims to understand the progression of road roughness and to model the evolution of road roughness (PROVENCHER 1995). An interesting finding of the study is the so-called „vulnerability index“ that quantifies the relationship between road gradient and likelihood of surface damage. FERIC (Provencher 1995) contributes to understanding serviceability trends for specific Canadian forest road conditions. A more general model with the ability to explain serviceability trends is still missing.

METHODOLOGY

Subject matter model

The deterioration process of aggregate-surfaced roads is not well understood. Most of the available information is based on feelings and experience of engineers. AASHTO design guidelines mention that the major factors influencing the loss of serviceability are traffic, age, and environment. At present, the separate or the interacting effects of these factors are not clearly defined, especially regarding age (AASHTO 1986). Therefore rules of thumb like those of Hirt (1977) are used that give the factors influencing the decrease of serviceability: traffic volume, precipitation, road gradient, protection by canopy. Cross-section grading patterns have additional effects controlling surface drainage and therefore erosion.

In the present study the following vulnerability hypothesis was used:

$$p_{distress} = f(gradient, precipitation, canopy, grading, traffic)$$

where

$p_{distress}$	*probability that a specific distress occurs (table 1)*
gradient	*road gradient*
precipitation	*annual precipitation*
canopy	*protection of road surface by canopy closure*
grading	*cross-section grading pattern (figure 2)*
traffic	*traffic volume*

Environmental effects include several processes such as erosion due to precipitation, clay swelling, and frost heave. In most cases, time is a net negative factor, too, that works to reduce serviceability. The model hypothesis limits its components to those effects that probably have the biggest influence and that may be measured or evaluated easily. The dynamic effect of time would need observation over longer periods and is therefore omitted.

Study layout

A factorial layout was used to investigate the vulnerability hypothesis. Using the three factors „cross-section grading pattern“, „canopy protection“, and „precipitation“ a 2^3 -design was used to classify available data records from Lienert (1983). He divided up a road network of about 300-km situated in the central part of Switzerland hierarchically into branches, sections, and sampling units. A total of 4575 sampling units of aggregate-surfaced low-volume roads were available, corresponding a total road length of 92,726 m. The frequency of the combinations of factors is presented in table 2.

Grading Pattern	Canopy Protection	Precipita–tion	Sampling Units
cambered	existing	low	60
cambered	existing	high	727
cambered	none	low	61
cambered	none	high	331
horizontal	existing	low	528
horizontal	existing	high	1546
horizontal	none	low	240
horizontal	none	high	1082

TABLE 2. Layout for the observational study. Sampling units from Lienert (1983) were classified by three factors, namely cross-section grading pattern, canopy protection, and precipitation.

The classification is unavoidably very unbalanced. However, the extent of available data is unique. Road gradient is available as a covariate for each sampling unit whereas information about traffic was only evaluated roughly and therefore was excluded from investigation.

Data sampling

A sampling unit is the smallest division of a road network consisting of homogenous road conditions (Eaton et al. 1987). Lienert (1983) recorded physical variables of pavement features, environmental parameters as well as categorical variables of road surface distresses for each sampling unit. The parameters recorded for each sampling unit are listed in table 3.

Variable type	Variable	Measurement (constant within each sampling unit), extracted from Lienert's (1983) data
Response	Pothole occurrence	binary (0/1)
	Erosion gully occurrence	binary (0/1)
Covariate	Road gradient	percent (%)
Factor	Grading pattern	two levels: C cambered, H horizontal
	Canopy protection	two levels: E existing, N none
	Precipitation	two levels: L (1400 to 1600 mm), H (1600 to 2000 mm)

TABLE 3. Variables used in deterioration analysis of aggregate-surfaced roads. Data were extracted from Lienert's (1983) investigation.

The definition of the binary response variables needs to be specified. While Eaton et al. (1987) give exact descriptions of the different distresses, Lienert (1983) just evaluated if a certain distress appeared and additionally evaluated the severeness quantitatively using the levels (1) slight, (2) moderate, and (3) heavy. In the present study levels (2) and (3) are regarded as distress while level (1) is added to the non-distress part. Covariates are continuous variables whereas factors are categorical.

Statistical analysis

The response variable of the model is binary (see table 3). In those cases it is usual to use logistic transformation of the response variable to fit a regression model. Factors were included using coding procedures transforming categorical data into metric variables. All the analysis was done using 0/1-coding (treatment coding). Analysis was carried out by logistic regression applying the following strategy:

- fit a model with all covariates and factors of table 3;
- select a series of sub-models by dropping variables that are not significant;
- choose two-way interactions of the sub-models;
- evaluate non-linearity of the covariates (road gradient).

Fitting the parameters of a logistic regression was done with generalized linear model fitting procedures of S-Plus (see Venables and Ripley, 1994). Non-linearity of the covariate *road gradient* was evaluated using power transformation. The most appropriate transformation was derived iteratively by looking for the exponent that produced maximal partial deviance.

RESULTS AND DISCUSSION

Distresses of aggregate-surfaced roads

Two types of distresses were investigated, erosion gullies and potholes (table 1). Equation [1] gives the model fitted for erosion gullies. Logistic regression analysis results in relationship [1]. To get the probability, the logit-transformed response variable has to be retransformed using equation [2].

$$\text{Logit(gully)} = -5.93 + 2.28 \cdot \text{grad}^{0.3} - 2.25 \cdot \text{PAT} + 0.49 \cdot \text{CAN} + 1.46 \cdot \text{grad}^{0.3} \cdot \text{PAT} \quad [1]$$

where grad = road gradient [%]
PAT = cross-section grading pattern [0/1]
0 for horizontal, 1 for cambered
CAN = canopy protection [0/1]
0 for existing canopy,
1 for no canopy

$$p = \frac{e^{\text{Logit}}}{1 + e^{\text{Logit}}} \quad [2]$$

where p = probability of gully occurrence [0...1]
Logit = value calculated by equations [1], [3]

Figure 4 visualizes equation [1]. Road gradient is the main effect of road surface erosion processes, followed by cross-section grading patterns. Using a camber significantly reduces the occurrence of erosion gullies. The relevant effects grow with increasing road gradient. Canopy closure also has a significant influence. Several previous studies investigated the process of road deterioration. Provencher (1995) developed a road deterioration model that quantified the role of road slope. His model distinguished between favorable and adverse gradient. His vulnerability index increases by a factor of about six between 2% and 8% slope. This finding agrees quite well with the model configurations „horizontal grading without canopy protection“. All other model configurations of figure 4 result in a smaller influence of road gradient. Reasons may be the smaller traffic in the study area and different grading patterns of road cross-sections, and different climatic conditions. Investigations about the influence of grading patterns on road deterioration have not been available. Foltz and Elliot (1997) described in detail how the processes of rut development and surface erosion work. They found that flow path length of surface water has bigger influence on erosion than the properties of aggregate materials. Changing the grading pattern from „horizontal“ to „cambered“ influences the flow-path geometry directly. The bigger the camber the shorter will the flow-path of the water be between crown and edge of the road surface. The model configuration „horizontal grading with/without canopy protection“ reinforces the water-flow-path hypothesis. At the beginning of the study an influence of precipitation on surface erosion was expected. The analysis did not confirm this hypothesis. Variability of precipitation data was probably too small to extract a significant influence. Foltz and Elliot (1997) give another explanation. They found that there was little relationship between annual precipitation and sediment production. They recommend consideration of high-intensity precipitation indicators in future studies.

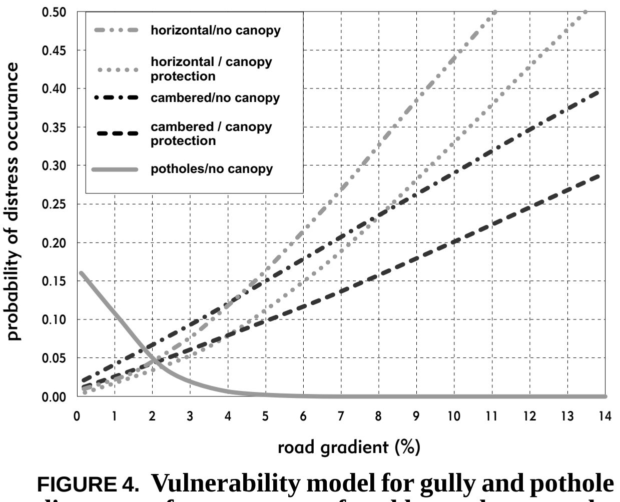

FIGURE 4. Vulnerability model for gully and pothole distresses of aggregate-surfaced low-volume roads.

$$\text{Logit(potholes)} = -2.31 - 0.34 \cdot \text{grad}^{1.5} + 0.36 \cdot \text{CAN} + 0.26 \cdot \text{PREC} - 0.10 \cdot \text{grad}^{1.5} \cdot \text{CAN} \quad [3]$$

where grad = road gradient [%]
CAN = canopy protection [0/1]
0 for existing canopy,
1 for no canopy
PREC= precipitation [0/1]
0 for 1400-1600 mm/a
1 for 1600-2000 mm/a

Equation [3] gives the model fitted for potholes that are presented graphically in Figure 4. Occurrence of potholes is opposing to that one of erosion gullies. The probability of potholes is maximal at a road gradient of 0%, and decreases considerably down to zero at a road gradient of 5 %. This finding quantifies what practitioners know from their experience. It was assumed that cross-section grading patterns would also influence the building of potholes. The analysis did not support this hypothesis. The main reason is probably structure of data. The study area is located in mountainous conditions where steep road gradients dominate. The cells of the study layout containing pothole distresses contained only few data records, which limited the meaningfulness of results at lower road gradients. An interesting finding is the influence on annual precipitation on pothole building. While the concentrated flow of surface water is the cause of erosion in gullies, potholes are built by ponding water. Therefore the total amount of water falling on a certain area is an indicator for pothole occurrence. Canopy protection reduces the pothole risk due to interception of precipitation.

Management implications

The results of the study will have several management implications for forest roads. Figure 5 summarizes the results by adding gully and pothole erosion probabilities for extreme variable values resulting in lower and upper erosion distress limits. To minimize the overall erosion risk, road gradients for aggregate-surfaced forest roads should be between 2% and 4%. If a cambered cross-section pattern is built and maintained, road gradients between 0% and 8% are within an acceptable range, and even gradients of 12% increase the erosion risk only by a factor of two.

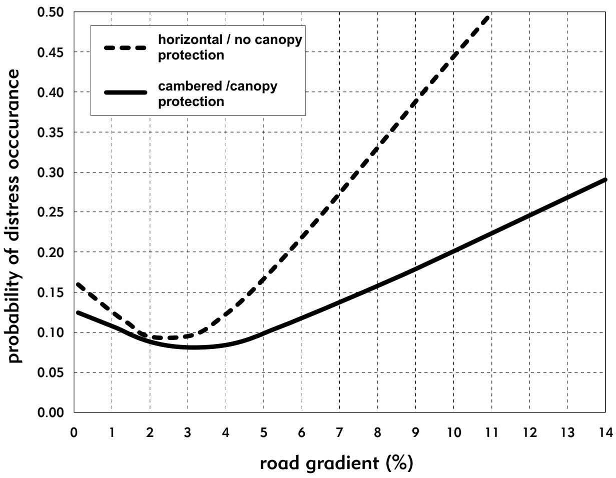

FIGURE 5. Vulnerability model for gully and pothole distresses of aggregate-surfaced low-volume roads.

Horizontal cross-section patterns should be avoided. For the investigated area it doubles the erosion risk of the pavement structure compared with horizontal grading. Increasing road gradient from 2% to 12 % multiplies the probability of surface erosion by a factor of six compared to a factor of 3 for the cambered cross-section.

CONCLUSIONS

The analysis of condition data of more than 90 km of aggregate-surfaced forest roads in Central Switzerland demonstrated that road deterioration due to surface erosion depends on different factors. The study resulted in five main findings: (1) gully erosion is the decisive deterioration process on inclined roads while potholes dominate on horizontal road sections; (2) the occurrence of erosion gullies depends on road gradient, cross-section grading pattern, and canopy protection; (3) the probability of pothole occurrence is at maximum at zero per cent gradient disappearing at 5% gradient; (4) cambered cross-section grading reduces gully distresses by a factor of about two compared with horizontal grading; (5) canopy protection of roads reduces gully occurrence by a factor of 1.3 to 1.5.

The relationship between road gradient and the probability of gully occurrence agrees with the vulnerability model of Provencher (1995). The pothole distress model gives new insights in the deterioration of horizontal road sections. The quantification of the effects of grading patterns and canopy protection is an important finding that will have implications on future pavement management strategies. The influence of precipitation could not be confirmed as expected. The reason is that annual precipitation that was available in the data is not a significant factor. Foltz and Elliot (1997) mentioned that there is little relationship between annual precipitation and surface erosion and recommend considering high-intensity precipitation. The study data represent a snapshot of the road conditions that did not permit investigation of the dynamics of deterioration. Future studies should deepen the understanding of the interactions between high-intensity precipitation, traffic, quality of aggregate materials and the road deterioration process.

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Forest Road Construction and Operation Systems: Considering the Environmental Effects on Steep Terrain

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ABSTRACT

Various small forestry vehicles play an important role in small scale forestry in Japan. Forestry vehicles running in the forests cause soil disturbance and soil compaction. By keeping vehicles at the roadside and working with their cranes or winches, soil and trees will be protected. When constructing strip roads by balancing cut and fill volume, earthwork, cut height and roadbed width increase rapidly when the slope exceeds 20 degrees. Earthwork of roads of 3 m in width is about twice that of roads of 2 m in width. Unless the degree of slope exceeds about 25 degrees, even a road of 3 m in width will be able to keep the cut height below 1.4 m. In Japan, this value is empirically the maximum allowable height so as not to cause erosion. However, where the slope exceeds 30 degrees, the road width must be kept below 2.2 m in order to maintain the cut height below 1.4 m. The loss of growing site by constructing roads of 3 m in width at the density of 100 m/ha is about 7 percent. These results will be useful to determine the size of vehicles and forest road planning in mountainous areas.

KEYWORDS--*Forestry vehicles, strip road, earthwork, road width, cut height*

INTRODUCTION

Various small forestry vehicles play an important role in small scale forestry on steep slopes in Japan. They are sometimes called mini-forwarders. Most of them are equipped with winches or cranes for yarding and loading and can be operated by a small crew. They vary in width from 1.2 m to 2.3 m and run on a number of different undercarriages such as wheels, crawlers, rubber crawlers, half-tracks, etc.

To realize maximum operational efficiency, these forest vehicles require a dense road network. Forest roads make such operations as harvesting, pruning, thinning, fertilizing, and so on, convenient and ensure a high quality of timber. These operations help to promote sustainable forestry.

As the road width increases, transportation becomes more efficient, but earthwork and construction costs increase and the impact on the forestland become serious. Indeed, high operational efficiency by a small-sized machine on a narrow road is ideal, but in general, as machines become smaller, disadvantages of reduced power and endurance increase. We analyzed the environmental effects of strip roads on the forestland.

ROAD WIDTH AND EARTHWORK

Here, a strip road is defined as a low-standard road, which does not require retaining walls that increase construction costs. Strip roads are mainly used by forestry vehicles. The road width is about 1.53 m according to the size of vehicles. Moreover, the width of 2.5 m and 3 m will withstand the traffic of trucks of 2 t and 4 t, respectively, if the roadbed is strong and paved at least by gravel, and the radius of curves are secured.

Strip roads are constructed by one of two methods; mainly cutting or filling. Here, we consider a method of balancing the quantity of cut and fill as shown in Figure 1, which can be used to design a route which fits the contour of the slopes.

Let the degree of slope, road width, fill slope, cut slope, and width of fill in the road width be, w, a, b, and x, respectively (Figure 1). By convention, a and b are the ratio of horizontal length to the unit vertical height of 1 m and the widening of curve is negligible. A simple triangular side ditch is constructed with bottom, s, and depth, t. The purpose of this ditch is not only for drainage but also for preventing collapsed soil from the backslope accumulating on the road. When the degree of slope exceeds 33.7 degrees, the fill slope a = 1.5, which means that the horizontal length of 1.5 m against the vertical height of 1 m can not intersect the earth, so retaining walls are required. As it is empirically difficult to construct high density road networks on slopes greater than 35 degrees (Oohashi et. al. 1989), we consider slopes of less than 30 degrees.

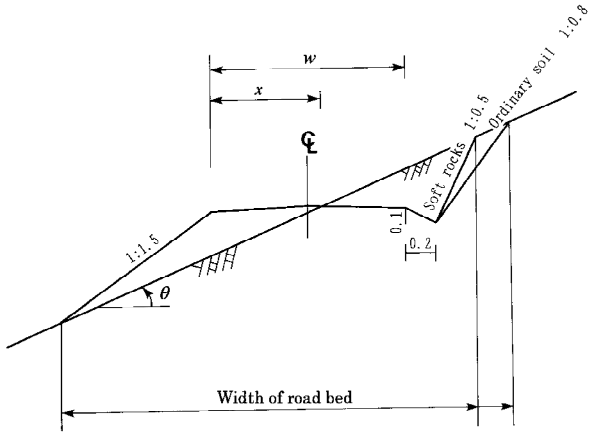

FIGURE 1. Roadway diagram. (Unit; m)

The cross-section area of fill is:

$$\frac{x^2 \cdot \tan\theta}{2(1 - a \cdot \tan\theta)} \tag{1}$$

and the width of fill from the earth to the base of slope is

$$\frac{x}{(1 - a \cdot \tan\theta)} \tag{2}$$

The cross-section area of cut is:

$$\frac{(w + s + b \cdot t - x)^2 \cdot \tan\theta}{2 \cdot (1 - b \cdot \tan\theta)} + \frac{(s \cdot t + b \cdot t^2)}{2} \tag{3}$$

and the width of cut from the top of slope is:

$$\frac{(w + s + b \cdot t - x) \cdot \tan\theta}{(1 - b \cdot \tan\theta)} \tag{4}$$

Let C be the ratio of earth volume after compaction to the original earth volume, and the section area of side ditch (st+t2b)/2 be negligible, from Equations (1) and (3),

$$\frac{x^2 \cdot \tan\theta}{2(1 - a \cdot \tan\theta)} = \frac{C(w + s + b \cdot t - x)^2 \cdot \tan\theta}{2(1 - b \cdot \tan\theta)} \quad (5)$$

then,

$$x = \frac{\sqrt{C} \cdot p(w + s + b \cdot t)}{\sqrt{C} \cdot p + q} \quad (6)$$

where ,

$$p = \sqrt{1 - (a \cdot \tan\theta)}$$

$$q = \sqrt{1 - (b \cdot \tan\theta)}$$

By substituting x in Equations (2) and (4) and adding them, the width from the base of the fill slope to the top of cut slope can be obtained. From Equation (3), the cut volume (m3) of a unit section is:

$$\frac{(w + s + b \cdot t)^2 \cdot \tan\theta}{2(\sqrt{C} \cdot p + q)^2} = \frac{x^2 \cdot \tan\theta}{2C \cdot p^2} \quad (7)$$

The fill area or cut area after construction can be obtained by multiplying Equation (7) by C. Fill height and cut height are:

$$\frac{\sqrt{C} \cdot (w + s + b \cdot t) \cdot \tan\theta}{p \cdot (\sqrt{C} \cdot p + q)} \quad (8)$$

and

$$\frac{(w + s + b \cdot t) \cdot \tan\theta}{q \cdot (\sqrt{C} \cdot p + q)} \quad (9)$$

respectively.

Let a = 1.5, b = 0.5 (when on soft rocks) or b = 0.8 (when on ordinary soil), s = 0.2, t = 0.1, C = 0.9 (when b = 0.5), and C = 0.81 (when b = 0.8). The values of x are shown in Table 1. Interestingly, these values are very similar to those reported for the investigated sizes of cross-section of actual stable roads on decomposed granite by Oohashi (1989).

	Road width (a=1.5, b=0.5, C=0.9)			
Slope	*1.5 m*	*2.0 m*	*2.5 m*	*3.0 m*
0°	0.75 m	1.00 m	1.25 m	1.50 m
10°	0.81 m	1.04 m	1.27 m	1.50 m
20°	0.72 m	0.93 m	1.14 m	1.35 m
25°	0.65 m	0.84 m	1.02 m	1.21 m
30°	0.51 m	0.66 m	0.80 m	0.95 m
	Road width (a=1.5, b=0.8, C=0.81)			
Slope	*1.5 m*	*2.0 m*	*2.5 m*	*3.0 m*
0°	0.75 m	1.00 m	1.25 m	1.50 m
10°	0.81 m	1.04 m	1.26 m	1.49 m
20°	0.75 m	0.95 m	1.16 m	1.37 m
25°	0.68 m	0.88 m	1.07 m	1.26 m
30°	0.55 m	0.71 m	0.86 m	1.02 m

TABLE 1. **Width of fill on the road surface (x) when constructing a strip road balancing the quantity of cut and fill**

Figure 2 shows cut volume from Equation (7). The cut volume of a road width of 3 m is about twice that of a road width of 2 m, and the cut volume increases rapidly when the slope exceeds 20 degrees.

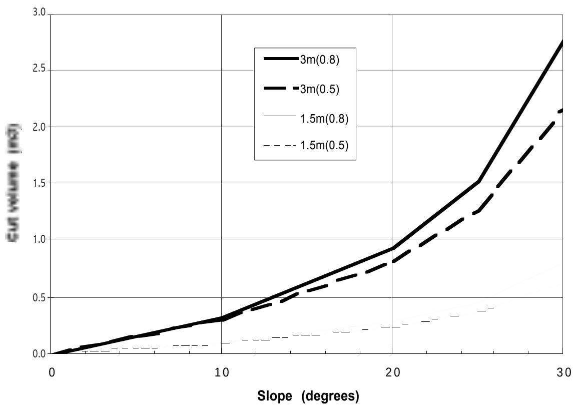

FIGURE 2. **Cut volume for degrees of slopes and road width. Figures of right ordinate; road width (slope of cut)**

Cut height is said to be more important than road width. In the case of low cut height, cut slopes become stabilized by rootlets (Oohashi et.al 1989). They are easily restored after damage by heavy rain, and there is little collapse. It is said empirically that a cut height of 1.4 m is the maximum allowable height so as not to cause erosion in Japan (Oohashi et.al 1989). From Equation (9), the cut height is

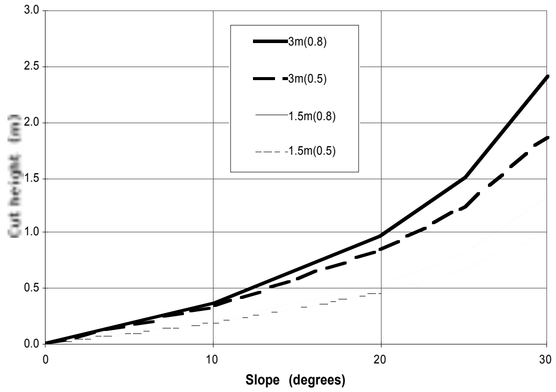

FIGURE 3. Cut height for degrees of slopes and road width. Figures of right ordinate: road width, slope of cut.

shown in Figure 3. The difference of cut height by increased road width is not so much as that of cut volume, but the cut height also increases abruptly when the degree of slope exceeds 20 degrees. There is a difference between the cut slopes of b = 0.5 and 0.8. Unless the slope exceeds about 25 degrees, even a road width of 3 m will maintain the cut height below 1.4 m. But where the degree of slope exceeds 30 degrees, the width of the road must be kept below 2.2 m even when the cut slope, b is 0.5, in order to maintain the cut height below 1.4 m.

The width of roadbed is shown in Figure 4. It relates to the road width and increases abruptly when the degree of slope exceeds 20 degrees. There is no distinct difference between cut slopes of b = 0.5 and 0.8. From the above results, the width of roadbed is related to the road width,

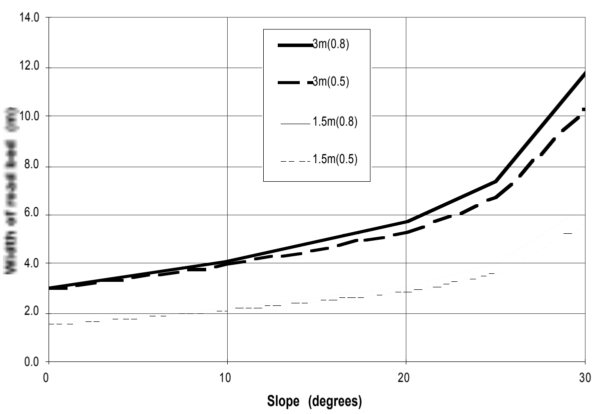

FIGURE 4. Width of road bed. (The ratio of road area to the forest site when the road density is 100 m/ha.) Figures of right ordinate: road width, slope of cut.

earthwork, cut height, and roadbed width increases rapidly when the slope exceeds 20 degrees. In particular, the cut volume increases when the road width exceeds 2 m. But occasionally, there is a desire to build wide roads when the logs are long or high transportation efficiency is necessary. Unless the slope exceeds about 25 degrees, even a road of 3 m in width will be able to maintain the cut height below 1.4 m. But when the slope exceeds 30 degrees, the width of road must be below 2.2 m in order to keep the cut height below 1.4 m, even when the cut slope, b is 0.5.

EFFECT OF ROAD CONSTRUCTION ON FOREST SITE

Generally, forestry vehicles running in the forests cause soil disturbance and soil compaction. It is said that the soil compaction lasts several years or several decades after only the first several passes, and that land productivity decreases as a result. Resisting capacity of the A0 horizon is as low as 0.9 kg/cm^2 (Kumakura et.al. 1993), so it can not endure the contact pressure of wheeled tractors of 1.0 to 1.5 kg/cm^2. Also, residual trees often suffer damage by operations and are polluted by oil. By keeping vehicles at the roadside and working with their cranes or winches, soil and trees can be protected, although roadbeds reduce the forestland.

In Canada, loss of forestland by road and landing areas is defined as an allowable soil disturbance. For example, allowable soil disturbance is 4% for a very sensitive site, 9% for a sensitive site and 19% for a not so sensitive site (Krag et al. 1991). Relative disturbance of forest sites by logging operations is said to be 20% to 35% for tractors, 11% to 16% for high-lead, 5% to 14% for skyline systems, and 5% for helicopters. According to these standards, appropriate logging systems can be determined.

From Figure 4, the ratio of road area to the forest site when the road density is 100 m/ha can be obtained by replacing the unit of m with %. For a density of 50 m/ha, the values decrease to half of those of 100 m/ha. Therefore, the loss of forestland by constructing roads is related to the road width. It increases rapidly when the slope exceeds 20 degrees. On slopes of under about 25 degrees, where a strip road of width of 3 m can be constructed within the cut height limit of 1.4 m as mentioned before. The loss of growing site by constructing these roads at a density of 100 m/ha is about 7 percent. The estimation of this value is very difficult, but it is similar to the value of skyline logging in North America.

CONCLUSIONS

When constructing high density road networks, the earthwork, cut height, and road bed width increases rapidly when the slopes exceed 20 degrees. The cut volume increases when the road width exceeds 2 m. Unless the degree of slope exceeds about 25 degrees, even a road 3 m in width will be able to keep the cut height below 1.4 m. The loss of growing site by constructing roads of 3 m in width at the density of 100 m/ha is about 7 percent. But when the slope exceeds 30 degrees, the width of a road must be below 2.2 m in order to keep the cut height below 1.4 m even when the cut slope is 0.5. These results will be useful to determine the size of vehicles and forest road planning in the mountainous areas while considering the environmental effects.

Furthermore, the road surface can be considered a drainage facility. Distributed drainage, permeable pavement, roadbed and partial pavement are favorable.

It is most important for realizing optimal sustainable forest management to vitalize forestry by improving the infrastructure of forests in relation to the environment.

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1. The title is tentative translation from Japanese title by the authors of this paper

Effects of Litter Fall on the Prevention of Soil Erosion in the Forest

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ABSTRACT

In Japan, sugi and hinoki are very typical species for plantations. It is known that soil erosion occurs in hinoki plantations more often than in sugi plantations. Actually, there is very little litter on the ground in hinoki plantations while the ground is covered with litter in sugi plantations. The objectives of this study are to show the amount of eroded soil and their seasonal variation in both sugi and hinoki plantations and to clarify the effects of litter on the prevention of soil erosion. The observation was carried out and ANOVA was used for the analysis. As a result, it was found that the amount of eroded soil in hinoki was larger than in sugi. It was notable that the amount of eroded soil in hinoki plantation on steep slope was the largest. On the other hand, the amount of eroded soil was very little regardless of inclination when there was a land-cover such as sugi litter or snow in winter. We also estimated annual soil losses to be 1.77 to 2.36 t/ha in sugi plantations and 7.55 to 25.86 t/ha in hinoki plantations. Finally, a risk map of soil erosion was shown based on the analysis.

KEYWORDS--*Soil erosion, seasonal variation, ANOVA, risk map*

INTRODUCTION

Most human activities involve risks and risk analysis. Management offers a scientific framework for studying and reducing risks. Risk analysis starts by identifying hazardous processes that are characterized by frequency and magnitude (Heinimann, 1995). This study focuses on the risk of soil erosion in the plantation forest, which may lead to soil degradation and/or decrease of water yield and quality. In Japan, sugi (Japanese cedar, *Cryptomeria japonica* D. DON) and hinoki (Japanese cypress, *Chamaecyparis obtusa* ENDL.) are typical tree species for plantations. It has been reported that soil erosion occurs in hinoki plantations more often than in sugi plantations. That is because hinoki makes up dense canopies and very little undergrowth can grow up on the dark ground underneath. Moreover, hinoki has scaly leaves and they can easily be separated into small pieces after they fall down on the ground. Thus, they are washed away by surface runoff on the ground. When litter is taken off the ground, aggregated structure in the A_0 horizon is broken by splash impact and subsequently infiltration rate decreases. As a result, it is said that surface runoff occurs and water yield from the forest decreases. Such situations must be avoided since forests are considered as important for water conservation. This study clarified the amount of eroded soil in both sugi and hinoki plantations and the effects of their litter, that is, mainly fallen leaves on the prevention of soil erosion. Finally, we showed a risk map of soil erosion based on the results of this study.

FIGURE 1. Study area

FIGURE 2. Photo of a plot in sugi plantation

METHOD

The study area was located in a private forest, Gifu prefecture, as shown in Figure 1. For the purpose of observation, six plots in total were installed in 25-year-old hinoki and 27-year-old sugi plantations, whose slopes were 27, 32 and 37 degrees for both species. The plots were 2 m in length and 0.5 m in width as shown in Figure 2. An automatic rain gauge was also placed near the plots. The observation was carried out from September 20, 1995 to March 22, 1997. We collected eroded soil on or around the 20th day every month. In the hinoki plantation, there was very little litter on the ground while the ground was covered with a lot of litter in the sugi plantation. In order to show the effects of litter on the prevention of soil erosion, the amounts of eroded soil were compared between sugi and hinoki

RESULTS

The results of observation were shown in Figure 3. Rainfall data in October 1995, November 1995 and May 1996 is missing because of battery trouble. According to the figure, hinoki, on a slope of 37 degrees had by far the largest amount of eroded soil. On the other hand, sugi had a smaller amount of eroded soil, and was not dependent on the slope degree. That was because in sugi the ground was covered with much litter. It was also noted that the amount of eroded soil showed seasonal variation partly depending on precipitation and it was very small from January to March 1996. Actually, this time of the year is winter season and the ground was covered with snow. In 1997, the ground was covered with snow only in February. Just after this winter season, the amount of eroded soil was extremely large. For example, there was a lot of erosion in April 1996 and in March 1997. It is said that such a phenomenon is caused when frost pillars are melted and it does not occur when the ground is completely covered with snow. The results of the observation show that such a phenomenon can be avoided when the ground is covered with sugi litter or snow in the winter season. This phenomenon is also often the case in cut and fill slopes of forest roads. Revegetation work is considered as a practical measure against such erosion. As for forestland, some silvicultural practices like the introduction of undergrowth and increase of litter on the forest floor are needed for the prevention of soil erosion. Therefore, forestry operations such as pruning and thinning are the best way for soil conservation, especially in hinoki plantations. Table 1 shows summary of the observation. According to this table, annual soil losses were 1.77 to 2.36 t/ha in sugi plantations while such losses were 7.55 to 25.86 t/ha in hinoki plantations. Especially in hinoki, on steep slope, landcover is considered very important to prevent soil erosion and it would be an effective measure to intentionally supply hinoki plantations with an additional litter supply.

We analyzed the relationships between the amounts of eroded soil and two factors such as tree species and slope by using ANOVA. The factors and categories are shown in Table 2. In the analysis, the data observed in 1996 was used . The result is summarized in Table 3. According to this table, all factors and interaction are significant at the 1% or 5% level. The contribution of tree species is the highest, which makes up as much as 66.1%. Main effects and interaction are shown in Figure 4 - 6. Figure 4 shows clearly that soil erosion in hinoki is much greater than in sugi. Similarly, Figure 5 shows that the amount of soil

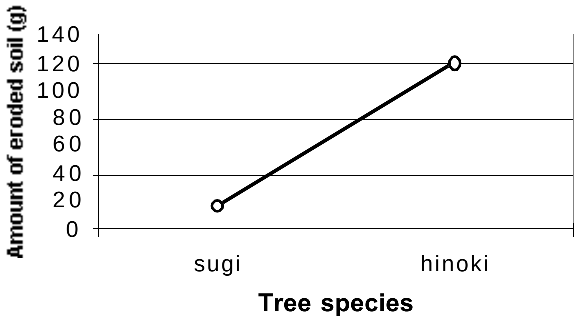

FIGURE 4. **Main effects of tree species.**

	Total amounts of eroded soil (g)	Total amounts of eroded soil in 1996 (g)	Estimated eroded soil amounts in 1996 (t/ha)
sugi (gentle)	447	182	1.82
sugi (medium)	462	177	1.77
sugi (steep)	578	236	2.36
hinoki (gentle)	1987	755	7.55
hinoki (medium)	1365	937	9.37
hinoki (steep)	4565	2586	25.86

TABLE 1. **Factors and categories of soil erosion**

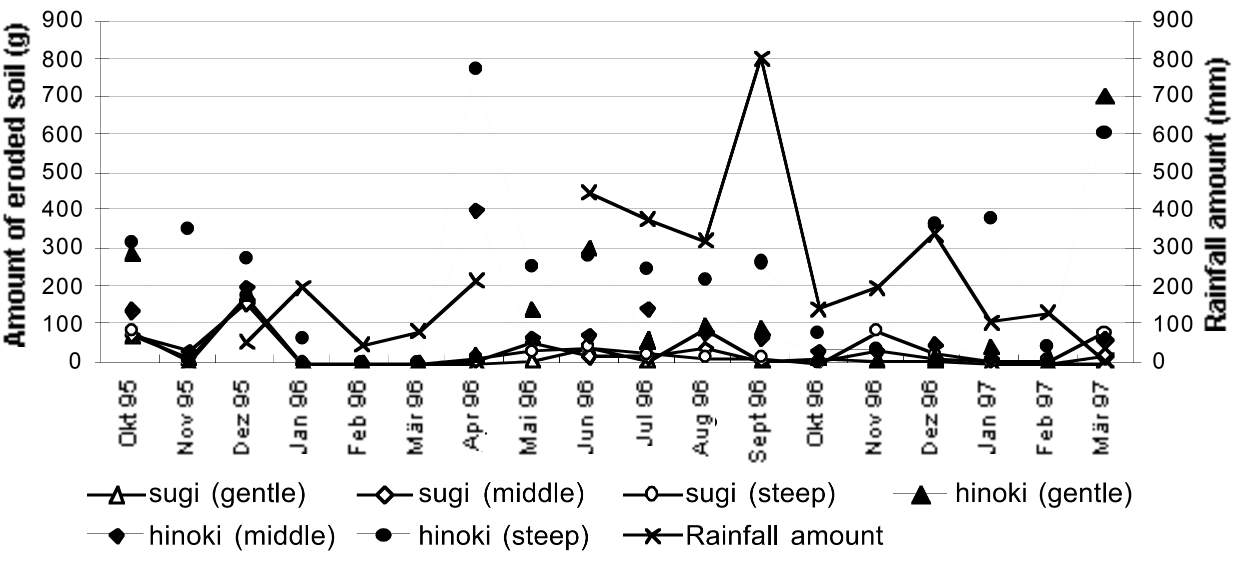

FIGURE 3. **Seasonal variation of soil erosion.**

Factors	Categories
Tree species (X1)	sugi
	hinoki
Slope (X2)	Gentle (27 degrees)
	Medium (32 degrees)
	Steep (37 degrees)

TABLE 2. Factors and categories of soil erosion.

Factors and interactions	Degrees of freedom	Sums of squares	Mean squares	F values	Contri–buting portions (%)
Tree species (X1)	1	188309	188309	16.7**	66.1
Slope (X2)	2	45133	22567	4.0*	15.8
X1 × X2	2	39723	19861	3.5	13.8
Errors	66	11293	171		4.3
Sums	71				100.0

TABLE 3. Summary of ANOVA

erosion depends on degree of slope. Figure 6 shows the amount of soil erosion in hinoki on steep slopes is extremely large.

FIGURE 5. Main effects of slope.

Finally, we made a risk map of soil erosion based on the results of ANOVA, which was applied to the Kyoto University Forest in Wakayama as shown in Figure 7. Such information would be helpful for decision-making of silviculture, forest and watershed management, estimation of site index, design of forest roads and drainage. Blank areas are mostly natural forests.

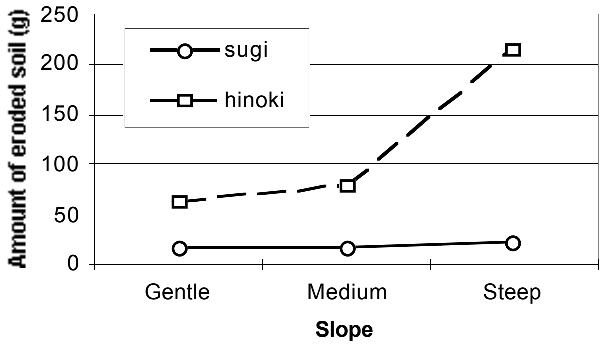

FIGURE 6. Interaction between tree species and slope.

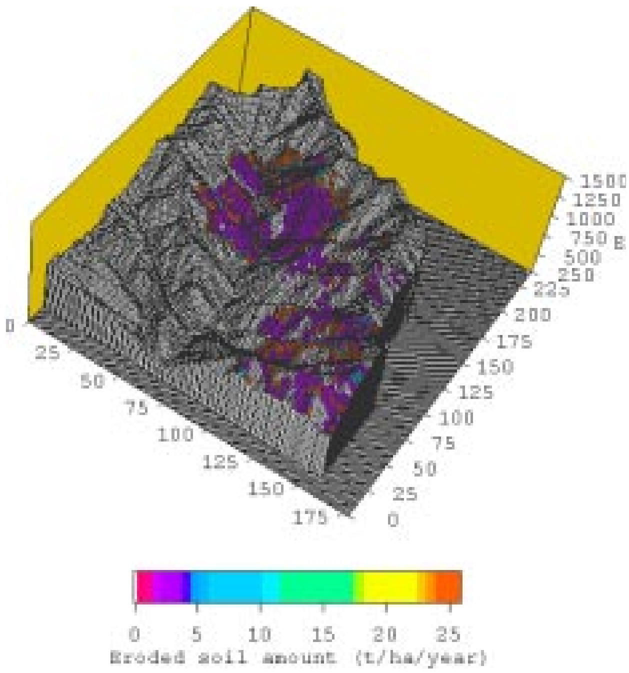

FIGURE 7. Risk map of soil erosion.

CONCLUSIONS

In this study, the amount of eroded soil was clarified depending on two factors; tree species and slope. We also estimated annual soil losses in sugi and hinoki plantations quantitatively. In conclusion, land-cover such as sugi litter is effective for soil conservation regardless of degree of slope. In Japan, processors are now widely used for limbing and bucking combined with full tree logging and produce an enormous amount of litter on forest roads or landings. It would be beneficial that such litter removed by logging be returned to hinoki plantations for soil conservation, which could reduce annual soil loss in hinoki plantations. Further research on soil erosion will be done in natural forests, on forest roads or beside streams in mountain forests in order to complete a risk map of soil erosion.

ACKNOWLEDGEMENT

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Part 4

Timber Extraction Technology

An Overview Of Timber Transport In Bhutan

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ABSTRACT

In steep terrain conditions that are dominant in Bhutan, extraction and transportation of timber are difficult and expensive operations that need special attention. The paper gives a survey on systems used for timber transport, transport techniques, and on prospects for improvement of timber transportation and extraction technology.

Cable cranes are the common equipment to yard logs from stump to roadside. A total of 18 cable yarding systems from different European manufacturers (Gantner, Nesler, Koller, Wyssen) are used. In some areas agricultural tractors and crawler tractors have been operated to skid logs over short distances. Manual skidding was quite used in the past and is still applied today. An interesting alternative system was evaluated: mule track roads of 1.5 meters width to transport split logs with power tillers (small agricultural tractor). Indian manufactured TATA trucks are standard for road transport. Future improvement should put the focus on three measures: improvement of ground-based equipment such as cable-skidders, forwarders; change of road building equipment such as excavators to replace bulldozers; practical training of workers such as handling tools and equipment.

KEYWORDS-- *Timber extraction, cable cranes, road transport of timber.*

INTRODUCTION

This paper focuses on two categories of timber movement and the methods used for transporting timber from the forest stump site to the intermediate depots and end use point. Emphasis is placed on yarding with cable cranes for short distance transportation and on its operation efficiency. The performance of trucks found to be commonly used for long distance secondary transportation, is examined in relation to its suitability in mountainous terrain like Bhutan.

The various techniques applied for loading, off-loading and stacking are not discussed in this paper.

BACKGROUND

Since the creation of the Forestry Department in 1952, the logging activities were confined to the Southern districts until the early 1960's, when the first motor road was constructed between Phuntsholing and Thimphu. The availability of manpower for unskilled labour, easy gentle slopes along the southern foothills and accessibility to the road network in India were the main contributing factors for early logging work in Bhutan.

The system of harvesting timber products and disposal was similar to the common practices prevailing in India then; i.e. the sale of whole demarcated forest harvest areas through auction.

The method used in skidding of logs was dragging by means of animals like elephants, buffaloes and bullock carts. For the same short distance transportation, farm tractors were used in some places like Kalikhola and Phibsoo in Sarpang.

SYSTEMS OF TIMBER TRANSPORT

Transportation of departmental timber

The major logging operations take place in the planned forest management units. In a topographic conditions with steep slopes and broken terrain like Bhutan the use of cable cranes is becoming the common form of cable skidding for timber transport from the stump site to the landing place or road head. In some cases manual dragging of logs from the felling sites outside the cable corridor to the cable line is also done. Depending on the slope at the working place the wheeled tractors with or without winch are also engaged for skidding of logs.

The timber is transported to the sale depots by trucks and tractors. In the depots final arrangement for disposal is made after taking log measurements. The timber is graded, sorted, and stacked for disposal to various markets: local, industrial and export.

Transportation of timber from the depots to final destination is the responsibility of the purchaser.

Timber transportation in rural areas

Manual methods account for a very large part of the transportation process in rural areas where the timber is allotted for use on a tree basis. In areas where road accessibility is difficult, a lot of time is used in transportation as the hand sawn timber of various sizes has to be either dragged or carried on backs from the forest to the house construction site. A direct transportation of timber from forest to the construction site by any transport mode helps rural people.

TRANSPORT MACHINERY AND TECHNIQUES

Cable systems

The cable cranes, tower yarder and in some areas like Chuzomsa in Wangdue District the use of gravity skylines are used to transport timber to road head within a distance ranging from 500 to 2000 metres. The different cable brands used in Bhutan are *Gantner, Nesler, Koller and Wyssen*.

Two tower yarders are available with the FDC at Rimchu (FMU) and one is in the workshop. The yarding of timber is limited to 500 metres.

Cable crane operation efficiency: a case study

In 1989 a comparison of some cable lines installed in different forest units under IFDP, Bumthang was carried out to study the operation efficiency in mixed conifer forest. The summary of findings from the study is:

- The optimal crew size is 6-8 men beyond which results in low productivity.
- The privately managed cable crane shows higher performance efficiency.

A similar study was conducted in 1992 for developing rates for transportation of timber by cable crane and the findings are explained below.

District	Management	No. of equipment	Ownership
Tashigang	Khariphu	1	Departmental
Haa	Haa east	2	”
Thimphu	Gidakom	1	”
Mongar	Kurichu	1	”
Bumthang	Mangdechu	2	Private
Haa	Haa east	1	”
Thimphu	Changang	2	”
Sarpang	Chaplikhola	1	”
Bumthang	Chendebji	1	”
Bumthang	Dhur	1	”
Bumthang	Karshong	2	”
Wangdue	Khotokha	1	”
Thimphu	Gidakom	2	”
	TOTAL:	**18**	

TABLE 1. **Availability and distribution of over head cable yarding systems.**

- The extraction of poles and firewood was 1.6 times more time consuming than the extraction of logs and blocks
- Transportation consumes the most time in the cable crane operation

Mounting	11.4 Man days/100 mtr	<30% of the time
Transport	24.2 Man days/100 mtr	<60% ”
Dismantling	- 4.3 Man days/100 mtr	<10% ”

Skidding by tractors

In certain cases wheeled tractors with rubber tyres have been used for short distance skidding on steep slopes and hauling on simple logging roads whenever manual dragging is not possible or time consuming. *Ford* model farm tractors used in agriculture are engaged in forest logging operations mainly for ground skidding when installation of cable line is found uneconomic or difficult. The farm tractors with a power supply ranging from 50 to 80 hp are used either with or without a winch connected to the power take off of the tractor. Improved devices to facilitate haulage of logs by farm tractors over short distances have not been tried.

Along newly constructed forest road the timber (logs, poles) lying scattered both above and below the road are skidded with a crawler tractor (bulldozer). As road construction and skidding of logs are done simultaneously it is economic to use bulldozers for such purposes in the forest.

AUCF (Alternative utilisation concept in fir zone) — a trial in fir forest

A trial was started at Hurchi, Bumthang in 1990 to study the utilisation of fir stands to increase fir timber recovery without constructing expensive forest road and using cable cranes. A mule track of 1,800 metres was constructed manually in 1994 to facilitate primary transportation of split fir logs by small tractor (Power tillers). From the preliminary data collected in 1994, it has proved viable to use small tractors on a mule track road of 1.5 metres width.

Motor trucks for long distance transportation

The Indian TATA (4 x 4) trucks are widely used in road transport for carrying timber and other commodities. In general the trucks used in Bhutan have dual rear axle and single axle drive with a gross vehicle weight of 6 tonnes. In difficult road conditions the trucks with dual axle drive are found to be very efficient for transporting timber. The small size DCM trucks with single axle drive are also employed for transporting blocks, cants and other forms of light timber on low gradient roads with good surfaces.

The design of truck varies with the nature of work and distance of road. A flat bed truck with wooden platform and without side flaps or stakes is commonly used for transporting timber from forest road head to the depots. The timber load is secured on the truck platform by ropes. This type of truck without side boards is to facilitate easy loading and unloading of timber and to increase the number of trips depending on the distance.

For long distance timber transport from Bumthang to Phuntsholing or Thimphu to Phuntsholing, trucks with side boards or with the load secured with wooden stakes or ropes are the common techniques used for transporting timber.

At the Integrated Forest Management Project (IFMP) at Ura the highly improved timber body TATA trucks with steel bunk units are used for transportation.

CONVENTIONAL METHODS OF TRANSPORTATION

Manual skidding

The manual dragging, rolling or carrying on backs and shoulders are found to be the cheapest form of transport in a small forest areas for extraction of limited timber volume when installation of cable crane is not economically viable.

For transport of large beam size sawn timber for huge Dzong construction and institutional buildings the timber are carried on the shoulders by crews of 30 to 40 people or more with the use of chains or ropes and poles. Forest logging operations carriage by men is always done on contract, the rate paid on volume basis.

A simple technique locally known as ”log channel” is done by placing round billets in front of the log to act as rollers. It is commonly practised to facilitate dragging of logs down hill slopes. This is mostly done for transport of ”cants” or beam size sawn timber from the forest to the road or landing site.

River floating

Timber transport by water is not a usual practice in Bhutan. However, trials were made on river floating at Anakha in Haa and in Chamkhar Chhu in Bumthang. The experience shows that the use of waterway as a means of transport is not very encouraging due to considerable loss of timber during floating operations. Water floating is therefore found not very suitable in a large part of our rivers due to swift currents in summer and cold icy water in winter.

PROSPECTS FOR IMPROVEMENT

Considerable progress has been made in developing the appropriate technology for logging and transport since the inception of the first five year development plan in Bhutan. In a fragile mountainous terrain like ours the environmental consideration has become an integral part of the development planning process for implementation of forest operations. It is for this reason and because of manpower shortage that the mechanized forest operations have substituted for many of the manual forest tasks. The use of the overhead cable skidding for instance is to help achieve the desired timber productivity and avoid damage from ground based transport to the greatest extent possible. An attempt is therefore made in this paper to consider the following few points which would contribute to make further improvements in timber transport method and techniques.

Improved equipment devices for ground skidding: Appropriately designed devices for skidding of logs like arch, chokers and wire cable for farm tractors would improve the efficiency of ground transport. The wheeled skidders could also be tried as a back up facility for salvaging large and heavy logs in difficult terrain. The forwarder with loading boom (Penz loader) is also being tried in IFDP to study its suitability in difficult forest sites. This forwarder with hydraulic grapple loader will facilitate the transport capacity.

Forest roads: The total length of forest roads constructed in the country as of 1995 is 681.41 kms and 366.5 kms of mule tracks. For construction of forest road in mountainous terrain, adequate attention must be paid to avoid the impact of erosion with appropriate engineering works and re-vegetation measures. Also due to environmental reasons, the network of forest roads is restricted to the absolute minimum and cable yarding is the preferred alternative. The use of hydraulic excavators and modern rock drilling machines will be needed to replace the erosion prone techniques using bull dozers. An examplary forest road was constructed by IFMP in Ura. The initial cost is quite high but it is believed that maintenance will be easy over the years to come. A standard formation width of 4-5 metres with proper route layout planning is necessary in steep terrain like Bhutan.

Procurement of tools, equipment and spar parts: For a suitable management of the forest the selection of appropriate tools, equipment and machinery is of great importance. The research (RNR-RC) could contribute in this development process of choosing the suitable methods, tools and equipment’s considering several operational criteria. One of the major difficulties faced by the private entrepreneurs is the procurement of spare parts for various tools and equipment such as cable cranes, mobile yarders, and tractors. The Ministry of Trade and Industry could play a leading role in identifying the manufacturing companies or suppliers from outside the country to provide an uninterrupted supply of required spare parts. This would also help in setting up basic technical standards and service capacity for equipment.

Practical training: Human resource development at the implementation level needs to be improved to enhance the quality of work in the field. The practical training schemes on logging and transport as experienced by IFDP in Bumthang is found to have a positive contribution although the training at present is confined to the trainees from NRTI and the BFI forestry sector. In the near future it may be useful to conduct a similar training course with emphasis on handling of logging tools and equipment and their maintenance for the private entrepreneurs and the field staff of both the Forestry Development Corporation and other projects of the Forestry Services Division.

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Utilization of a Monorail for Logging Sites in Steep terrain

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ABSTRACT

Forestry work in steep terrain still relies on human labor. Mechanization of this work is a pressing need. Monorails have been highlighted as a means to transport workers. Recently, a tram-car for slopes which exploits the advantages and the mechanism of the monorail, has been developed to improve work efficiency and to decrease the work burden in steep terrain.

The tram-car runs on two rails (main and sub-rail) and can transport not only workers but also thinnings. As the tram-car uses a rack-and-pinion driving mechanism, it can run at inclinations from plus 45 degrees to minus 45 degrees.

In order to prove the safety of the tram-car, we measured the stress of ground structures and compared the measured values with the design calculations. As a result, the load and stress were smaller than the calculated values and under the allowable values. At the same time, in a two-year ongoing field test, the working efficiency has improved by 7 to 25% compared with manpower operation. Moreover, the cost of tram-car maintenance has been less than 1/3 the cost of forest road maintenance.

KEYWORD---*Steep terrain, monorail, tram-car, working efficiency, safety*

INTRODUCTION

There is a lot of steep terrain in Japan, and the mechanization of forestry work is a pressing need. However, forest road construction is lagging, there are fewer forest workers and their average age is increasing. The monorail has been identified as a means to eliminate the walking commute, to improve work efficiency, and to decrease the work burden.

The purpose of this paper is to report on the current state of the monorail in Japanese forestry and the newly developed tram-car for slopes.

CURRENT STATE OF THE MONORAIL

The monorail for forestry was developed about 1970 as a transport machine for agriculture and has been introduced as a small-scale hauling machine for thinnings and bedlogs for shiitake mushrooms. However, as the forestry machine changed to vehicle systems such as the mini-forwarder, the monorail did not gain popularity.

The strength and safety of monorails has improved in recent years and they have been gaining attention as a new machine that is safe and can transport a large number of people. The Labor Ministry recommended “Safety guidelines for forestry monorails” in April 1996 and legal standards were provided.

The number of monorails for forestry use has been increasing since about 1985, especially in the past few years (Figure 1). Monorails for forestry have been introduced in the Kinki, Shikoku and Chubu districts, where many of the areas are very steep and forestry is small-scale (Figure 2).

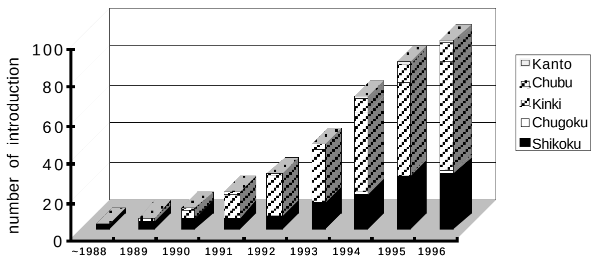

FIGURE 1. Transition of the number on monorails in forestry

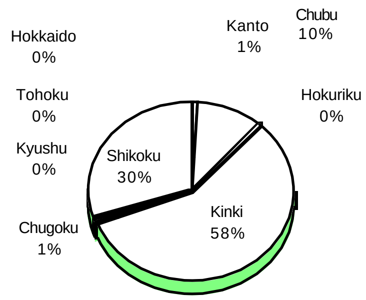

FIGURE 2. State of introduction of monorails in forestry per district.

The advantages of the monorail include:

- Shortening of commuting time
- Reduction of fatigue from commuting
- Low cost of installation
- Low maintenance costs
- Suitability for small-scale work
- Effectiveness in forest environmental maintenance

Thus monorails are increasing in popularity.

DEVELOPMENT OF THE TRAM-CAR FOR SLOPES

The tram-car was developed to shorten commuting and shuttle time to the work site and improve work efficiency. This machine not only carries out wood but also can transport machines, materials, and workers. It can ascend and descend slopes of up to 45 degrees by utilizing the mechanism of the monorail. We thoroughly considered safety and durability in designing the tram-car, because it transports many workers and heavy objects (Labor Ministry 1993, Jinkawa et al. 1995).

An outline of the tram-car is shown in Figure 3. The main specifications of the tram-car are shown below.

1. Power truck

- Water-cooled 4-cycle, 3-cylinder diesel engine with a modified deep oil pan
- 2 hydraulic driving wheels with built-in hydraulic multi board disk brakes
- Hydraulic driving gear system
- Fail-safe system
- Capacity of 3 people

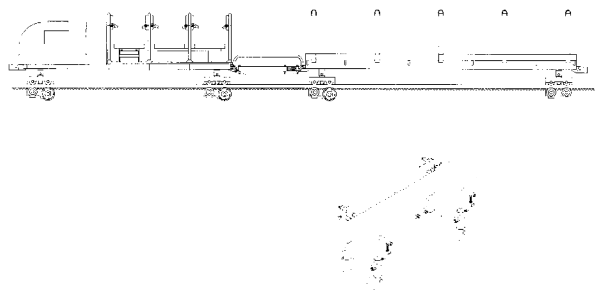

FIGURE 3. Outline of the tram-car.

2. Transport truck
- 1,000kg in maximum loading weight
- One hydraulic driving wheel
- 4,200mm in length x 600mm in width

3. Connecting devices
- Universal coupling rod
- Main- and Sub-connecting devices

4. Rails and props
- Two rails (main-rail and sub-rail)
- Rack-and-Pinion drive
- Prefab rail method
- Derailment prevention mechanism

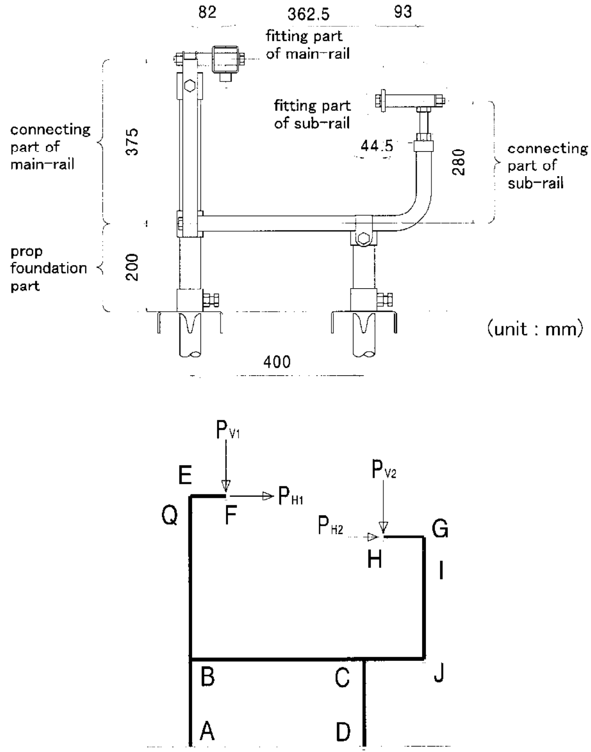

FIGURE 4. Outline of ground structure and model for structural analysis.

SAFETY OF THE GROUND STRUCTURE

The safety of the ground structure is important in the safe operation of the tram-car. Thus, to prove its safety we analyzed the stress of the ground structure. In this analysis, the calculated values of stress and load were compared with the measured values, which were obtained from running examinations of tram-cars.

Method of calculating stress and load

The ground structure has a complex rigid-frame structure, which is composed of rails, props, metal fittings, and bolts, etc (Figure 4). The ground structure was divided into seven components, then the stress and load added to each component were calculated. We assumed that the rail is a continuous beam and the prop is a support point, and used the expression of three moments when the concentrated load acted on each span (Taira 1984).

Stress measurement examination

We did the running examination of the tram-car with a load of 195kg (one driver + two 65kg weights) installed in the power truck and a load of 1000kg (fifty 20kg weights) installed in the transport truck. Stress was measured with strain gauges attached to each component of the ground structure. The average inclination of the measurement site was 2 degrees.

Comparison between measured and calculated values

The measured and calculated values of the stress of each component are shown in Table 1. These values were identical for the main rail and the main rail side materials. On the other hand, the values were different for other materials, apparently because, the center of gravity of the weights shifted from the position in the calculation.

Nonetheless the measured values of each component were below allowable stress, proving that operation was safe.

USE AND EFFECT ON FORESTRY OPERATIONS

Tram-cars have been introduced in Shirotori Town and Higashishirakawa Village in Gifu Prefecture (Furukawa et al. 1995). We investigated the working efficiency and worker's consciousness before and after tram-car introduction, and examined the effect of the introduction of the tram-car.

Use and maintenance cost

An outline on the state of use and the maintenance costs of the rail and vehicle at the two sites are shown in Table 2. The Higashishirakawa work site adjoins a forest road, but the Shirotori site is 300m away from the road. Therefore, the work time per day is long in Shirotori. Moreover, as Shirotori is in a heavy snow zone, there is a necessity for withdrawing the trucks during winter and checking on rails during thawing of the snow. The unit maintenance cost is 159 yen/m in Shirotori and 31 yen/m in Higashishirakawa. However, the unit price for road repairs at the Shirotori site is 500 yen/m. Therefore, expenditures for the new systems are less than one-third previous costs.

	Shirotori Town	**Higashishirakawa Village**
Content of work	***planting, tending, thinning***	***tending***
Use district area	10ha, 21ha, 15ha	15ha
Rail distance	550m	450m
The horizontal distance from forest road	300-750m	0-600m
The height distance from forest road	80-250m	0-220m
Slope	25-32degree	30-40degree
Used days	57day	50day
Used time	35.6hr	23.0hr
The maintenance costs (unit : yen)		
Withdraw cost (winter season)	32,000	
Control cost (weeding around rail)	13,000	14,000
Control cost (check after winter season)	42,500	
Total	87,500 (159 yen/meter)	14,000 (31 yen/meter)
Fuel cost	5,248	1,886
Oil cost	4,125	3,788 (1.7 liter/hr)
Total	96,873	19,674

Part	**Material**	**Size** (mm)	**Yield point** (kgf/mm^2)	**Allowable stress** (kgf/mm^2)	**Bogey measured value** (kgf/mm^2)	**Bogey calculated value** (kgf/mm^2)	**Bogey** (kgf/mm^2)		**Bogey** (kgf/mm^2)		**Bogey** (kgf/mm^2)	
							mean	c.v	mean	c.v.	mean	c.v.
Main-rail	STKR400	60x60xt3.2	25.0	14.7	8.73	8.69	4.16	4.71	12.06	12.92	12.47	13.64
Sub-rail	SS400	t9x50	25.0	14.7	0.74	1.06	1.10	2.22	5.43	7.09	11.75	7.74
Prop	STK500	48.6xt2.3	36.2	21.3								
Connecting part of main-rail												
Metal fittings	SS400	50x33.4xt3.2	25.0	14.7	5.52	8.20	5.73	5.14	6.78	13.75	6.50	13.18
Prop	STK500	48.6xt2.3	36.2	21.3	4.55	3.64	4.76	2.28	8.05	6.11	7.35	5.86
Connecting part of sub-rail												
Bolt	S45C	M24	35.2	20.7	2.53	2.01	6.99	5.38	11.32	12.89	15.16	12.90
Arm	STK400	34xt2.3	24.0	14.1	0.65	0.48	1.81	1.29	2.93	3.10	3.92	3.10
Prop foundation part												
Prop	STK500	48.6xt2.3	36.2	21.3	4.82	3.52	5.21	2.19	8.39	5.93	7.54	5.68
Arm	STK400	34xt2.3	24.0	14.1	–	–	–	–	–	–	–	–
Fitting part of main-rail												
Bolt	S45C	M16	35.2	20.7	6.83	6.16	4.47	3.87	10.20	10.33	9.78	9.91
Pipe	STK500	28xt5.5	36.2	21.3	9.31	12.47	10.08	7.82	15.19	20.92	14.14	20.06
Fitting part of sub-rail												
Bolt	S45C	M16	35.2	20.7	0.48	0.35	1.22	0.95	1.70	2.27	2.20	2.27
Pipe	STK500	28xt5.5	36.2	21.3	1.05	0.72	2.45	1.92	3.85	4.60	3.51	4.60

TABLE 1. Size of materials, measured and calculated values of stress

Effect of introduction

To investigate the influence on the working efficiency by introducing the tram-car, we examined the work and log operation of both sites.

In Shirotori, seedlings were transported with the skyline logging system before the tram-car was introduced, but now seedlings and workers are transported by tram-car. A comparison of the working efficiency before and after the introduction of the tram-car shows that the working efficiency of planting and brush cutting improved 7 to 25%, though the commuting distance was increased (Table 3).

On the other hand, this improvement in efficiency was not seen at the Higashishirakawa site, because the area adjoins the forest road. However, we investigated worker's consciousness, they said "Working time becomes long", "The rest time decreases", and "It's easy on the way home". The effect of the introduction of the tram-car was thus confirmed.

Influence of slope

We calculated the total amount of labor when the seedlings were transported by manpower, skyline logging system or tram-car, based on the working efficiency results for Shirotori Town (Figure 5). The slope of the footway was 10 degrees and the walking speed was assumed to be 30m/min ascending and 45m/min descending (Yamada 1986), and the running speed of the tram-car to be 50m/min.

For manpower and the skyline logging system, slope had a large effect on the total amount of labor. However, when the tram-car was used, the total amount of labor was constant. Therefore, we can see that the effect of introducing the working efficiency increased as slope increased.

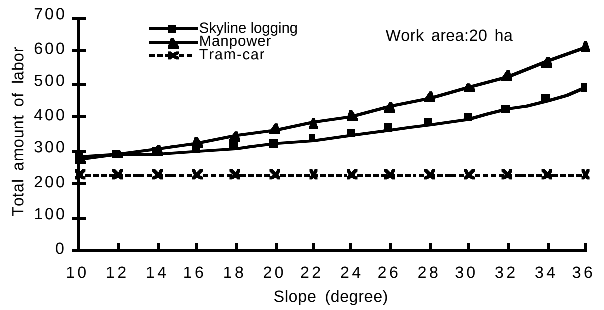

FIGURE 5. Simulation of the requested amount of labour as a function of ground slope.

CONCLUSIONS

The monorail has been highlighted as a means to improve forest work efficiency in steep mountains. Its use is increasing rapidly in western Japan.

We developed a tram-car for slopes which utilizes the mechanism of the monorail. The tram-car can transport not only workers but also wood and materials. In tram-car operation, safety and durability are important points. We analyzed the stress of the ground structure by a running examination. As a result, we were able to obtain measured values, which corresponded well with the calculated values. Moreover, the measured values were below the allowable stress, showing that the safety can be maintained.

Next, we investigated the effect of the tram-car introduction on two work sites and found that the effect of the tram-car introduction increased as the slope of the work site and distance from the forest road increased. Moreover, it became clear that the maintenance costs for one year were less than one-third the costs of the conventional

	amount of labor	Ratio	Labor cost	Materials cost	Overhead expenses	Total	Difference
Planting cost (Area: 10ha conversion)							
Before	116.7 persons	(100%)	2,479	1,194	1,036	4,709	0
After (A)[a]	87.8 persons	(75%)	1,865	1,194	810	3,869	-840
After (B)[b]	108.5 persons	(93%)	2,306	1,194	973	4,473	-236
Brush cutting cost (Area: 11.1ha)							
Before	24.1 persons	(100%)	513	7	190	710	0
After	19.1 persons	(79%)	407	5	151	563	-147

TABLE 3. The working efficiency before and after the tram-car introduction

a. 300 m walking from the terminal

b. 550 m walking from the terminal

system. From these results, we conclude that the tram-car is safe machine that is useful for improving the efficiency of forestry work.

ACKNOWLEDGMENT

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Yarding Operation Systems with Self-Propelled Hoist-Carriers

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ABSTRACT

About 1800 self-propelled hoist-carriers have been introduced into Japan since the early 1980's. An efficient yarding system using a self-propelled hoist-carrier was investigated at Tenryu District in Shizuoka Prefecture. A simulation was attempted by taking into consideration the spatial relationship between the position of the yarder and the timber. According to the simulation model on a standard setting (length: width=10:4), the optimum yarding operation depends on the configuration of setting, slope and conditions of the timber.

When the skyline could be set up parallel to the slope, it was more efficient to rig a skyline through the center of the harvest unit and carry out short-wood or tree-length logging without prehauling manually on the ground if the slope was 25 or 30 degrees. If the ground slope was 35 degrees, it was more efficient to rig a skyline on the lower side of the center after prehauling logs manually on the upper side of the skyline. When the skyline was rigged straight to the slope of 35 degrees, yarding without manual prehauling was efficient.

When the skyline was set up obliquely from the highest to the lowest level, it was efficient to rig a skyline through the center and gather short and tree-length logs, on a slope below 30 degrees. On a slope of 35 degrees, yarding preceded by manual prehauling was efficient.

KEYWORDS--*Self-propelled hoist-carriers, yarding, operation system, simulation model, operational efficiency.*

INTRODUCTION

Yarding of a self-propelled hoist carrier has prevailed widely since the early 1980's (Figures1&2). It was first introduced in the Kyushu District and then in the steep mountainous areas such as Gifu and Shizuoka Prefectures, central Japan. A total of 1,788 carriers have been employed mainly in the west districts by the end of 1995. As they are relatively small and low-priced they play an important role as equipment for supporting small-scale forestry management. This paper examines the operations with self-propelled hoist-carriers based on field investigations to serve as an aid for the development of forestry operations in steep mountainous areas and small-scale forestry management.

FIGURE 1. Self-propelled hoist carriage.

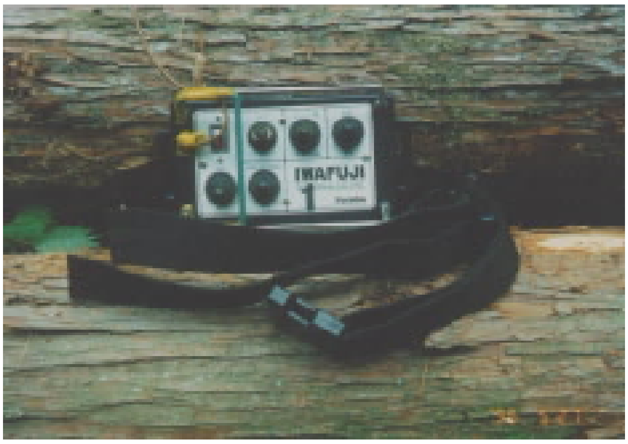

FIGURE 2. Radio control box.

MATERIALS

Investigations were carried out on a forestry contractor in the Tenryu District of Shizuoka Prefecture. Eight workers, in their thirties and forties, were employed by the contractor. The contractor owned three self-propelled hoist-carriers and the workers were well acquainted with yarding systems with self-propelled hoist-carriers. Daily work reports of eleven settings and three units were investigated (Figure 3).

FIGURE 3. Scene of a setting.

RESULTS

Factors influencing the yarding system were examined using correlation analysis on the daily work reports. Yarding production (m^3) and the amount of manpower (man-days) for felling and bucking were related to the manpower for yarding at a significance level of 1%, and rigging distance (=skyline length) and the number of riggings (=skylines) were related to the manpower for yarding at a significant level of 5%.

As a result of a multiple regression analysis, production volume, thinning intensity, and incline of slope greatly influenced the manpower for yarding and the regression of the amount of manpower (y_1) required for yarding short timbers including manual prehauling was obtained at a significant level of 1% as follows:

$$y_1 = 0.1605x_1 - 0.1185x_2 - 0.7393x_3 + 41.64$$

x_1: production volume (m^3),
x_2: thinning intensity (%),
x_3: ground slope (degrees).

And the regression of manpower required for rigging and dismantling (y_2) was obtained at a significant level of 1% as follows:

$$y_2 = 0.0272x_4 + 4.728$$

x_4: rigging distance (m)

Actually, 10.1 man-days and 15.5 man-days were required for rigging and yarding including manual prehauling, respectively, and the total was 25.6 man-days. According to the above regression equation, the expected manpower was 25.7 man-days, which is composed of 11.5 for rigging and 14.2 for yarding and prehauling.

SIMULATION MODEL FOR FORECASTING MANPOWER

A simulation model was constructed using the above results to calculate the operational efficiency according to the relationships between settings and skylines. It was assumed that the settings were "rectangular" length of cutting area: width of cutting area=10:4 and that skyline operation could be modeled using parabolic theory.

The results of this simulation were as follows:

1. When skylines could be rigged in the direction of contour lines and slopes were 25 or 30 degrees, it was efficient to carry out short log yarding or tree length yarding without manual prehauling where skyline was rigged at the center of the setting. However, when the slope was 35 degrees, it was efficient to rig a skyline at the lower part than at the center of the setting. In this case, logs above the skyline needed manual prehauling.
2. When a skyline was rigged in the direction of the slope, it was efficient on slopes of 25 and 30 degrees to rig a skyline at the center of the setting and to carry out short log yarding or tree length yarding. On the 35 degree slope it was efficient to rig a skyline diagonally to the setting and to yard after manual prehauling.
3. In the case of a skyline rigged at the center of the setting in the direction of contour lines, yarding without manual prehauling was more efficient. However, when the shape of settings was rectangular with "length of the cutting area: width of the cutting area = 10:8", it was more efficient on the 35 degree slope to yard after manual prehauling.

It is possible to find the optimum method with this simulation model according to the condition of the settings.

APPLICATION OF THE SIMULATION MODEL

To examine the preciseness of the simulation model, it was applied to short log yarding without manual prehauling under the same field conditions.

It was calculated that 21.7 man-days was required and the total efficiency of operation was reduced (Figure 4). On the other hand, the manpower required for the tree length logging system and the whole tree yarding system was estimated to be 18.5 man-days and 19.6 man-days, respectively. It was also expected in the case of whole tree yarding that the efficiency of bucking would be greatly improved by a processor on the landing. Considering the accuracy of this model, the manpower for the yarding system with a self-propelled hoist carriage and the manpower for manual prehauling was estimated to be 12.0 and 4.6 man-days, respectively, which is more than the actual value of each 11.0 man-days and 4.5 man-days. These dif-

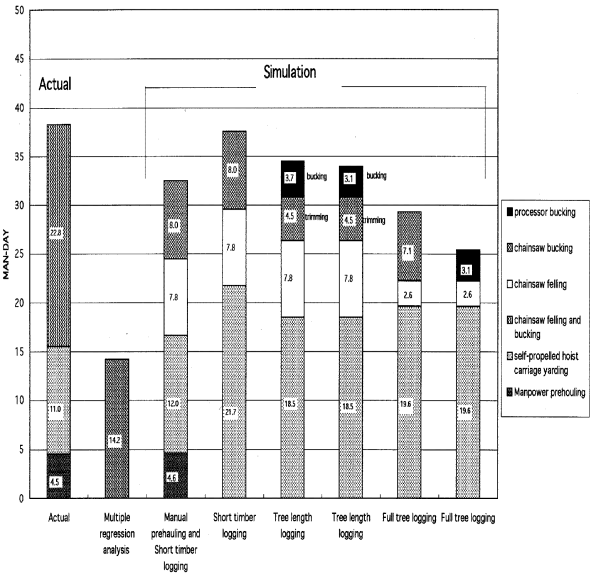

FIGURE 4. **Operational efficiency of the system.**

ferences are partly due to the difference between the assumed data for constructing the model and the actual data.

CONCLUSIONS

Yarding with the self-propelled hoist-carriers requires selection of the optimum rigging location and the proper operation method according to the shape and the slope of the setting area and conditions of the landing. It will be necessary to consider working cost, workers labor load, safety and other factors in the future.

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European Cable Yarders – a Review of the State-of-the-Art Technology

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ABSTRACT

Europe has a long tradition of using cable yarders for logging operations. Due to technical developments in ground-based logging, some older cable yarding technology has not been used for a long time. Some of this technology may provide a good solution for mountainous areas in developing countries. The decision on which cable yarding system to use is very important for the efficiency of the operation, much more so than for ground-based operations.

In recent years there has been considerable developments in cable logging equipment. In Europe small and medium size yarders are available for all kinds of logging.

The presentation will present the different systems and the range of topographic and operational conditions for the most common systems are given. A classification of the European yarders and carriages shows the available equipment for the different systems. The most common equipment is described and rough production figures are given. Additionally, the environmental aspects of the different solutions are presented.

KEYWORDS--*Cable yarders, carriages, cable systems, European yarders, skyline systems*.

INTRODUCTION

Many forest areas in all parts of the world are inaccessible for ground-based harvesting techniques. Sometimes the reason is the remote location of blocks to be harvested in combination with a very low road network density. Additionally there are a lot of productive forests in the world on sites where driving is not possible. Reasons for this can be the steepness of the slopes or the limited carrying capability of the soils. Possible logging systems for such sites are: cable logging, aerial logging (balloon or helicopter) and motor-manual techniques.

Cables or ropes are one of the oldest mechanical elements and have been used everywhere in the world for the transportation of people and goods (Samset 1985, Pestal 1961, Dieterich 1908). Cable transport was an important part of alpine transportation systems and is in most parts of the alpine region now substituted by a road network. A number of different systems are available for all kinds of transportation. The paper lists the systems and presents their operational conditions.

Harvesting and logging on steep terrain includes a lot of environmental risks. A high standard of forest engineering combined with the right logging techniques are required to minimise environmental impacts and maintain economically viable operations.

EUROPEAN YARDERS

The slope conditions which limits the use of ground based harvesting systems is between 30 and 40 % (Trzesniowski 1992). This is not the technical limit of skidders, but what is environmentally acceptable. On poor ground conditions ground based operations are not even possible on flat land. There are some differences between up- or downhill operations, but generally no loaded skidder should operate on land steeper than 40 %.

A large number of different cable yarding systems have been developed in many places around the world. The systems differences are variations of the configuration (number of lines, types of carriage, direction of transportation). Also the usage differs (layout of the cable corridors). All systems can be realized by mobile yarders - which are truck mounted, skidders or crawlers- or stationary systems (sled winches). Table 1 gives an overview of the available systems. This kind of classification uses only the number of lines and the method to produce the lifting force. Table 2 presents other ways of classifying cable logging equipment. In addition to that criteria, the management concept has the main effect on the system decision.

	number of lines			
Skyline type	**1**	**2**	**3**	**4**
Running skyline	lasso cable	high lead		
	endless cable systems	jammer		
living skyline		shotgun/ flyer	slack line systems	
Standing skyline (intermediate supports possible)	self propelled carriages	gravity systems	all terrain systems	all terrain systems
			south bend	
			north bend	

TABLE 1. Cable Systems.

criteria	variation
Anchoring	standing, living or running skyline
number of lines	one to four
Procedure	gravity or allterrain
Equipment related	self propelled, classical yarder, tower yarder, machine combinations
Mobility	stationary – mobile
Range	short, medium and long distance
Spans	single span, multiple spans
Payload	<15 kN; 15-25 kN; >25 kN
log length	cut to length / tree length

TABLE 2. List of criteria's used to classify cable systems (Trzesniowski, 1997 modified).

All the cable systems listed can be used for clear-cut operations. Just a few are realistically feasible in thinning operations. The main parameter is the horizontal deflection of the skyline during lateral hauling. For running skyline systems (and in live skyline systems with some restrictions) the pre-tension in the skyline is relatively low, so relatively wide corridors are required or considerable damage to the residual trees will occur.

A number of different carriages have been developed. Similar to the skyline systems, there is also a lack of an internationally accepted carriage classification system (Fernsebner 1992). The most common classification is given by Studier (1979) who uses the method by which the skidding line is brought out for his classification. Figure 1 gives the classification of carriages. In central Europe slack-pulling carriages are primarily used.

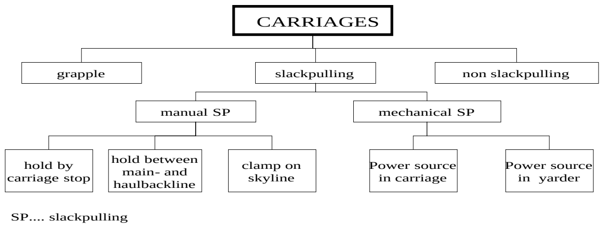

FIGURE 1. Carriage classification (Fernsebner 1992).

Attached directly to the carriages are the chokers compared to the grapple carriages which are common in Northern America and other areas which use their technology. For thinning operations and lateral skidding, a slackpulling carriage is necessary. Non slackpulling carriages work well only in clear-cut systems or when the loads are pre-bunched under the line .

There are two different types of layout used for cable operations. The type of setup has a big influence on the required road access. In the northwest part of America the fan-shaped layout is very common. Normally this type of layout uses access from the top. Due to the concentration of more lines on one landing the ratio of setup-time to productive time is good. Also the volume per setup is higher than in other layouts. The drawbacks are the concentration of soil impacts near the landing, the different lateral distances, the need of many anchors and the large size of the landing. This system is advantageous in large scale clear-cuts with no residual trees inside the harvest block.

The second type is the rectangular layout with parallel lines. For each line the whole equipment must be set up. The volume per setup is the volume per corridor. For that reason, the systems which take little time to setup are better. The benefits are smaller landings, no concentration of yarding lines and similar lateral hauling distances. The production per hour is lower.

There is always a relationship between the road layout and the cable corridor layout used. For the fan-shaped layout most of the roads are located on the ridge, with all the associated problems. For rectangular layouts with nearly parallel corridors the road should be situated at the upper third of the slope. In this situation it is possible to yard from the downhill slope up to the road and the upper part down to the road.

The performance (in the operational time) up or downhill depends on the line length, lateral hauling distance and inclination of the cable. Case studies on short lines (around 200 m) show a better productivity for downhill than uphill operations (Mitterbacher 1989). Line length over 300 m lose this benefit due to an tremendous increase of setup-time. Technically it is much simpler to yard uphill and the experience of the crew is not such a problem as it is for downhill yarding. For of this reasons uphill operations in Austria are more common than downhill yarding. Only the large forest enterprises and contractors use systems which can be used for up- and downhill operations (Loschek, 1997). In recent years such machines can be combined with a processor. The latest development in cable yarding in Europe are the self-propelled carriers which use the skyline for pulling themselves along the cableway.

In Central Europe five standing skyline systems are used today. In Scandinavia highlead systems are also used. Figures 2 to 6 list them in chronological order. Figure 2 shows the classical ”gravity system” where the winch is positioned on top of the line. The power source is just for

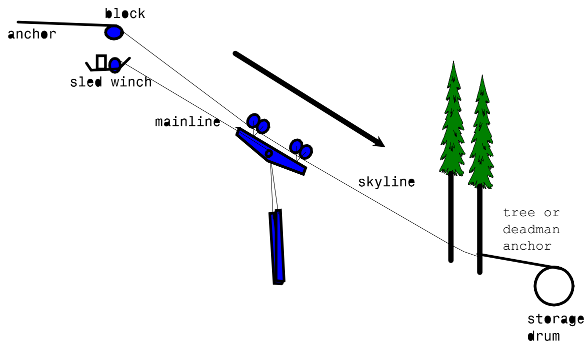

FIGURE 2. Downhill yarding with gravity.

lateral hauling and moving the carriage up. Gravity propels the loaded carriage downhill. The minimum inclination for such a system is 15 % (Trzesniowski 1997). The most important part of such a system is a high performance brake. The systems use slackpulling carriages which clamp to the skyline during loading and unloading. Radio control, time sequence, directional change or stop devices control the carriage. The productivity of the system is between 3 and 9 m^3/h. A traditional rule was (Pestal 1961) 1m^3 per meter line length to reach the economical break even point. The system is mostly used in final cuts (small clear-cuts, partial cuts).

Figure 3 gives an example of the two-line system which uses the gravity to return the carriage to the stand. The minimum inclination of the cableway is at least 22% (Trzesniowski, 1997) and depends on the internal rolling resistance of the carriage. This system is used with all sizes of yarders, but is preferable with small yarders in thinning operations. The K300 from the Koller company uses such

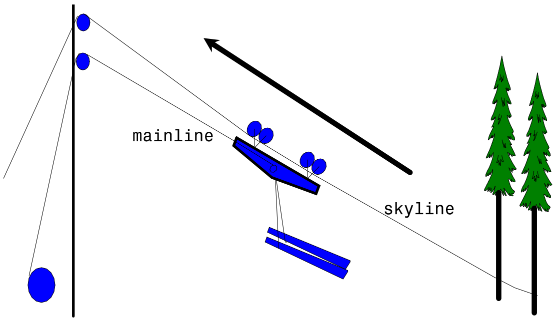

FIGURE 3. Uphill yarding, two-line system.

a system. The power source is usually an agricultural tractor. The most common system configurations allows loads up to 15 kN, which limits the system to thinning operations.

The systems is easy to set up and run. The systems use simple carriages with stop devices or mechanical clamping carriages. Different authors present productivity for such systems between 4 and 5 m^3/h for thinning operations in cut-to-length systems. Sometimes such systems are used to extract tree length. Due to the limitations in the payload and the decreasing speed of heavy loads they are not really suitable for tree length logging. Additionally, thinning long pieces increases damages on residual trees.

Figures 4 and 5 give the situation of all-terrain systems used in central Europe. The difference in both systems is

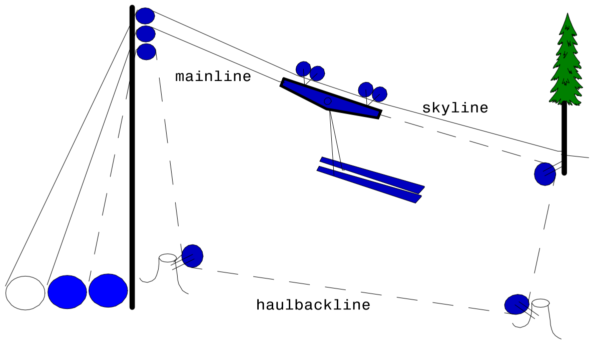

FIGURE 4. All-terrain yarding three-line system

just the type of carriage and the number of active drums. The three-line system use slackpulling carriages where the slackpulling is done by the haulback line, an internal power source or an auxiliary carriage. The four-line system has an additional drum on the yarder which operates a thin line to pull down the main line through the carriage. Most of the mid and large size yarders can operate with three or four-line systems.

The benefit of the four-line system is the simpler carriage with less mechanical parts inside the carriage. The four-line systems normally runs without clamping to the skyline. A repositioning of the carriage during lateral hauling and an adapting of the line length between carriage and load during inhauling is possible and makes the operations better to control. In three-line systems the same effect is possible with sophisticated radio controlled carriages. The productivity of these systems is between 5 and 8 m^3/h for the medium sized and 11 to 14 m^3/h for the larger European yarders. .

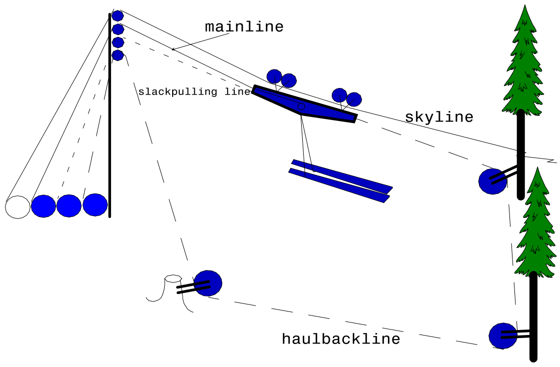

FIGURE 5. Allterrain yarding four-line system.

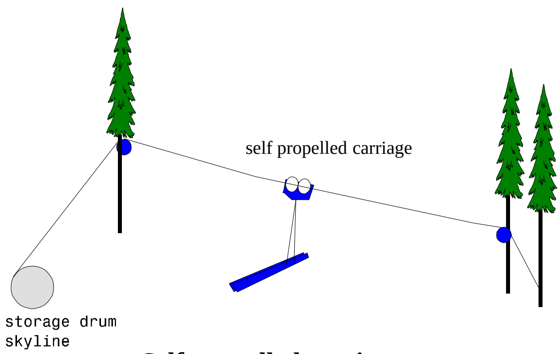

FIGURE 6. Self-propelled carriage

In the last 5 years self-propelled carriages have come onto the European market (Figure 6) This new system uses only one cable to carry the carriage/load and for its own movement. The line is wrapped around an internal wheel system and moves along the cable like a monkey. The weight of the system is relatively high and the velocity is lower than in conventional systems. The producer recommends a maximum span length of around 200 m. The lifetime of the skyline was a big problem in the beginning. With a reconstruction of the support jacket and some improvements in the driving system the cable problems should be solved. The system is a good solution for downhill yarding with tree length pieces.

Table 3 presents approximate information about the performance of medium sized yarders from the Austrian federal forest enterprise. These results show the nearly similar performance in up- or downhill operations. The skill level of the crews was high and the composition of the crews remained stable.

Yarding direction	Line length (m)			
	100	200	300	400
uphill	8.1	7.6	7.1	6.5
Downhill	8.5	7.9	7.3	6.8

TABLE 3. **Productivity of medium size yarders. (in m^3 per hour)**

CONCLUSIONS

With some exceptions, standing skyline systems are mainly used in Europe. The reason is the better lateral stability of the systems and associated with that the reduction of damages to residual trees. Small enterprises and contractors use the simple uphill two-line system, which can be used with less skilled crews and requires no sophisticated planning. A lot of contractors offer long distance cable cranes in the classical gravity system for downhill transportation.

The more sophisticated three and four-line systems are used only in larger forest enterprises. To run them requires better qualified crews and more intensive organization of operations.

For the conditions in mountainous countries with limited road access, the long distance cable cranes seems to be the best solution. The benefits are the simplicity of operation, the simple and robust equipment design and the long extraction range - up to 2.5 kilometers. For all-terrain needs the system can be adapted to run an endless mainline system. This operation needs a lot more of set-up time and requires a specially trained crew, but works for well for installations that run for longer time periods (for example the transportation of agricultural goods to another traffic system).

Spar yarders are good solutions for timber logging but need a well designed road network to reach the harvesting areas. For the usage of spar yarders the road design should split the forest slope at the upper third point. The road network should have enough storage places to set up the yarder and additionally have enough space for piling the logged timber. The drawback of the spar yarders is the blocking of the roads if there is not enough space.

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Application of Super Fiber Rope as a Guyline for a Mobile Tower Yarder

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ABSTRACT

'Super Fiber Rope' (SFR) is a newly developed chemical fiber rope which has higher strength and higher modulus. Replacing the wire rope of tower yarders with SFR is expected to lighten the mobile tower yarders and to decrease the work load for rigging. The utilization of SFR as a guyline was investigated.

Three types of rope (d=12mm, L=26m) were investigated: wire rope (6x19), Vectran (polyarylate fiber) rope, and Technora (para-linked aramid fiber) rope. Pulsating tension and bending were added to the samples on a nearly life-size machine. The relation between the reduction of rope strength and number of tension cycles (tension : release = 60sec : 20sec) was examined.

The part of the sample rope, which had undergone expansion and contraction on the sheave, was damaged the most. Technora rope began to break after about 35000 cycles, while the strength of wire rope was decreased to 60% less after only 12000 cycles.

Technora rope is thought to have enough strength and fatigue life to be used as guylines. However, it is difficult to estimate the fatigue life and strength loss from its appearance. Nevertheless, SFR loses its strength more rapidly than the wire rope. For the safe use of SFR, further careful management will be necessary.

KEYWORDS--*Super fiber rope, wire rope, mobile tower yarder, guyline, cable logging*.

INTRODUCTION

Some kinds of newly developed synthetic fibers, which have high strength and elasticity, are called 'Super Fiber'. The tensile strength of these fibers is much higher and the elongation is less than on usual chemical fibers such as nylon and polyester. Characteristics of these fibers are shown in Table 1.

Brand name	Com–positon	Tensile strength (kgf/ mm^2)	Elonga–tion (%)	Elastic Modulus (kgf/ mm^2)	Specific weight
Technora	Aramid	310	4.4	7100	1.39
Vectran	Poly–arylate	330	3.8	7600	1.41
Wire	Steel	180	1.7	20000	7.85
Nylon	Nylon6	100	18.3	560	1.14

TABLE 1. Specifications of different rope types.

The 'Super Fiber Rope' (SFR), made of Super Fiber, may be used instead of wire rope (WR) when lightness and corrosion resistance are required, such as fisheries and mooring ships. It also may be used in forestry, where replacing of WR with SFR is expected to decrease the work needed to set up cable logging systems and to lighten the mobile tower yarder. But the properties of SFR are weaker than WR (tolerance to wear, weather and heat). In this study, utilization of SFR for use as guylines on a mobile tower was examined.

The effects on lightening a mobile tower yarder by using SFR as guylines were calculated. The most common mobile tower yarders in Japan are equipped with 2-4 guylines, which are 25-50m long. Because the weight of SFR is about 1/5 that of WR, replacing all IWRC 6xFi(25) WR (f=12.5mm) guylines with SFR which has the same diameter, for example, will make the mobile tower yarder 27-108kg lighter. SFR is more flexible and softer than WR, so the size and weight of the winding drum can be reduced.

As for decreasing work intensity, lower physical exertion from pulling out lighter rope can be expected and non-oil SFR can keep clothes free from oily stains. Furthermore, the handling of rope will be come easier because of its flexibility.

The results of a fatigue test on this new fiber rope are reported and the possibility of utilization as guylines is discussed.

MATERIALS AND METHODS

Three types of rope samples were investigated: WR (6x19), Vectran rope (VR) and Technora rope (TR). Vectran is a polyarylate fiber (Kurarya Co. Ltd.) and Technora is a para-linked aramid fiber (Teijin Co. Ltd.). Details of these ropes are shown in Table 2.

Sample	Construc–tion	Nominal diameter (mm)	Lay length reed (mm)	Breaking load (tf)
Wire rope WR	6x19 O/O JIS[a] Grade A	12	77	8.0
Vectran VR	12 strands Braid type	12	49.1 [b] 56.3[c]	4.75[d]
Technora TR	12 strands Braid type	12	79.2[e] 81.2[f]	10.25

TABLE 2. Specifications of sample ropes.

a. Japanese Industrial Standard (JIS G 3525)
b. unloaded
c. loaded with 1.9 tf
d. broken at eye spliced point
e. unloaded
f. loaded with 1.9 tf

To test fatigue strength of SFR, examinations should be based on actual usage. A larger error will occur in accelerated fatigue tests which are applied to SFR, because (1) SFR is made from chemical fiber, so it tends to be affected by heat, and (2) SFR consists of numerous fine fibers so its internal stress distribution is complex.

Guylines are unwound from winding drums which are mounted on the appropriate site of the tower, pulled out through a pulley on the top of the tower, and fixed to the stumps or other anchors as shown in Figure 1. Because the tension generated by logging is loaded against the top of the tower, guylines will stretch. Some sections of rope will be bent by the pulley on top of the tower.

Rope fatigue tests under pulsating tension were conducted in this situation and a nearly life-size working model of a machine was used (Figure 2). A 6-inch guide-block, which is popular in Japanese forestry, was used as a bending pulley. The D/d value, i.e., the ratio of the sheave diameter to the rope diameter, was 10.58 at the bottom groove and 11.58 at pitch diameter. The tension generated by logging varies and it is not regular. Pulsating tension was simulated by the expansion and contraction of a hydraulic cylinder and the hydraulic cylinder was con-

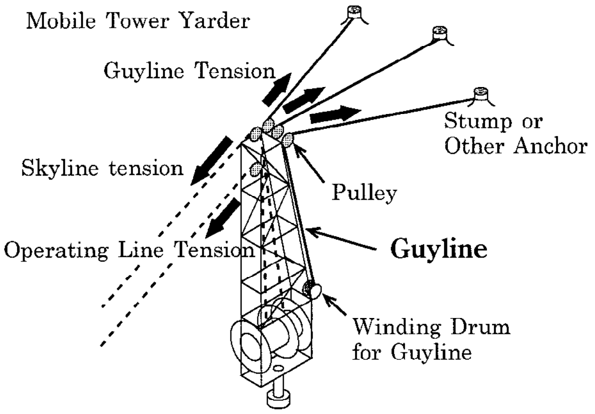

FIGURE 1. Tower yarder spar with attached guylines.

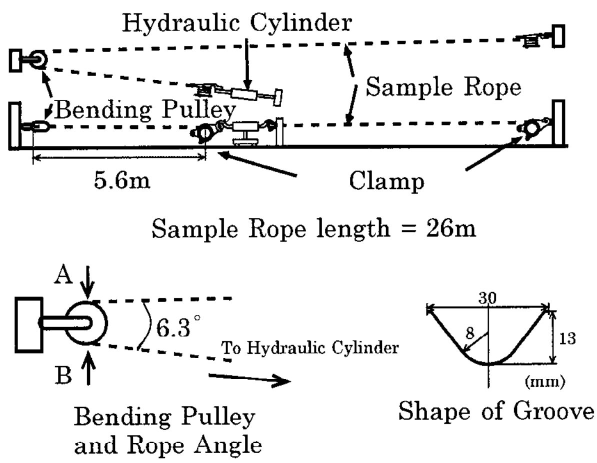

FIGURE 2. Testing equipment.

trolled by a timer and magnetic valve. One fatigue cycle consisted of high tension (60 sec) and low tension (20 sec). Figure 3 shows the change of pulsating tension during the cycle. The range of pulsating tension of SFR was smaller than WR (Table 3). Because the elastic modulus

Sample	Maximum load (kgf)	Minimum load (kgf)	Tension difference (kgf)
WR	1924	523	1401
VR	1790	756	1034
TR	1889	628	1261

TABLE 3. Characteristics of dynamic loading.

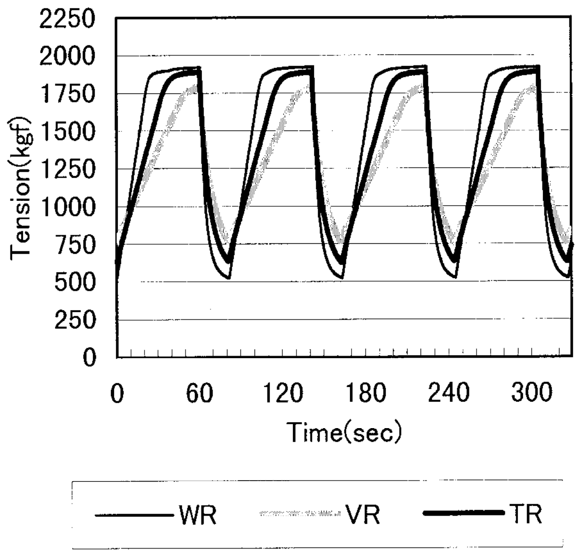

FIGURE 3. Passage of pulsating tension

of SFR was smaller than WR, more time was spent to change the tension levels when the cylinder was moved using a regular volume of oil.

RESULTS AND DISCUSSION

The pulsating tension test just described made sample ropes expand and contract repeatedly. As a result, the part of the rope undergoing expansion and contraction on the sheave was most damaged by the test. The strength of WR, VR and TR fell gradually as the wire/fiber broke.

To evaluate breakage, WR after testing was bent by hand, so breakage occurring at the nip of the rope was also counted. Breakage mainly occurred at points A and B shown in Figure 2, especially at point A, which was bent first under high tension.

Figure 4 shows the relationship between wire breakage at point A and the residual strength of the rope. When about 10% of all wires were broken (10% wire-breakage: the Japanese standard for replacing WR), residual strength fell to about 60% of the new rope.

With WR, the degree of strength loss could be estimated by counting the number of broken wires. However, in the cases of VR and TR, although the surface of rope became nappier as the fatigue cycles increased as shown in Figure 3, it was difficult to quantify nap.

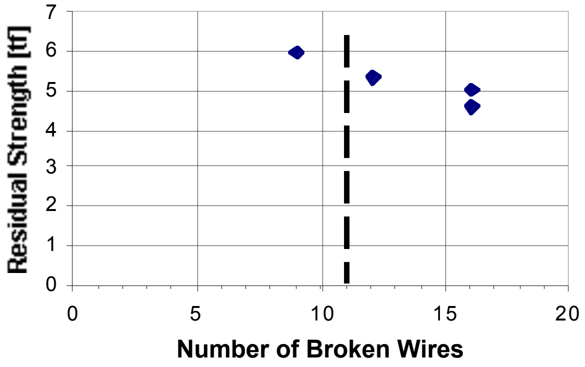

FIGURE 4. **Wire breakage and residual strength of the rope.**

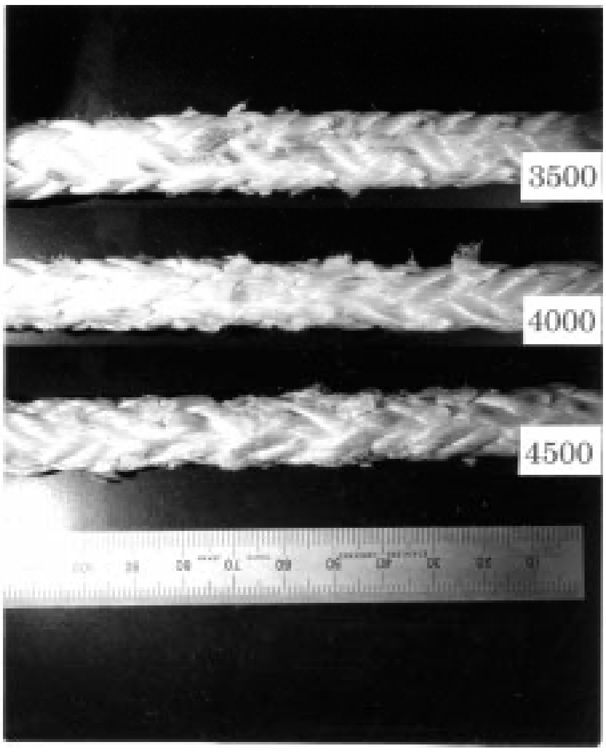

FIGURE 5. **Nappy surface of tested VR after 3500, 4000 and 4500 cycles.**

Figure 5 gives a visual impression of the napping effect of VR. The damaged sections of VR and TR were investigated in detail. Fiber breakage and nap occurred between strands on the sheave-free side (Figure 6). On the sheave contact side (Figure 7), fibers on the rope surface were rubbed and became felt-like. The abrasion of the surface was stronger in VR, because the elongation of VR was

FIGURE 6. **Sheave-free side.**

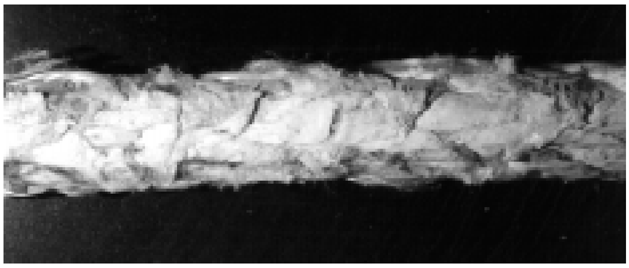

FIGURE 7. **Sheave-contact side.**

larger than TR. The elongation and contraction of the rope occurred at the part in contact with the sheave (about 19cm), causing surface abrasion on the sheave side. It was apparent that the strength of the rope was reduced by abrasion, but to what extent was not clear.

The number of fatigue cycles and residual strength of tested rope were plotted (Figure 8).

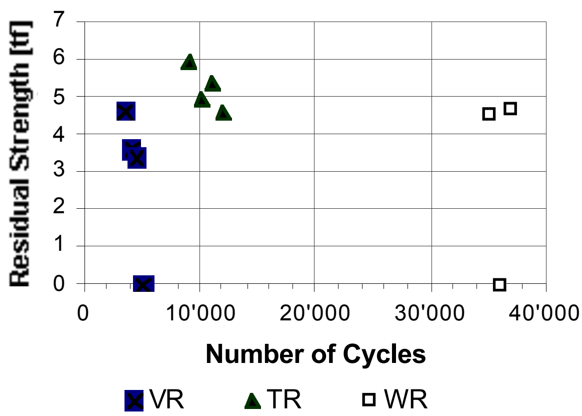

FIGURE 8. **Number of fatigue cycles and residual strength in tested roaps.**

The residual strength of WR and VR fell to about 70% of the original ones when the cycle number passed 11000 and 4000, respectively. The residual strength of TR after 35000-37000 cycles was less than 50% of the original strength. One sample of TR broke after 35732 cycles. The fatigue life of TR was about three times as long as WR, while that of VR was only about half of WR. The residual strength of VR decreased quickly when strength loss by bending fatigue began. The large scattering of residual strength data for TR can be explained by such a quick loss of strength. In this way, SFR lost strength faster than WR. In practical use, appropriate management of damage and determination of replacement time will be necessary to ensure the safety of operations. Above all, when using SFR, further careful checking and management will be needed because of its tendency to lose strength.

The braiding method of VR was thought to be a cause of quick strength loss. If the reed (corresponding to lay length of WR) of rope was short, the rope was tightened firmly and became hard and deformed. But as the angle between the load direction and strand direction become larger, internal stress increases and the breaking load decreases. The lay length (unloaded) of TR was 30.01mm longer than VR (Table 2) and its dimension stability was also different (Figure 9). VR quickly lost strength and the

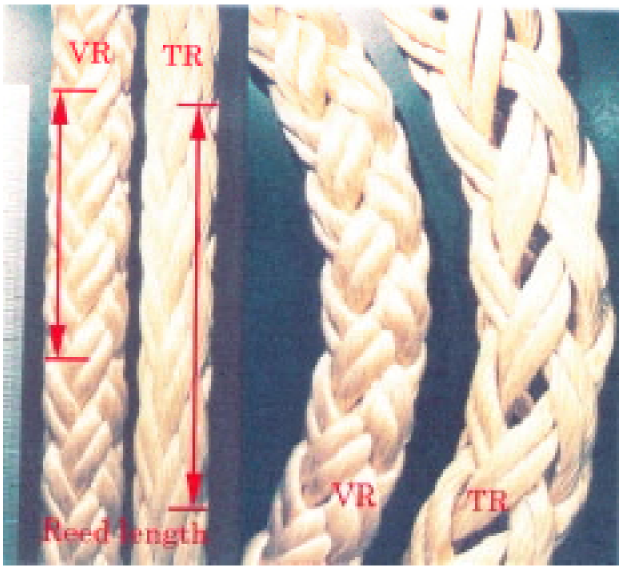

FIGURE 9. Difference in reed length and dimension stability between VR and TR

cycle number up to failure was smaller, although the range of stress caused by tension was narrowest. An investigation of fiber breaking and napping between strands was suggested that rubbing of strands and secondary bending caused by large internal stress led to quick fatigue.

The elongation of sample WR (26m) was 4.78mm/1000kgf, while that of TR and VR was 9.36 and 14.60mm/1000kgf, twice and three times as much as WR, respectively.

As shown in Table 1, the elastic moduli of Technora and Vectran were 7100 kgf/mm^2 and 7600 kgf/mm^2, respectively. But the elastic moduli of TR and VR, which were calculated from elongation, were 2267kgf/mm^2 and 3538kgf/mm^2, respectively. EM of wire and WR were 20000 kgf/mm^2 and 9623 kgf/mm^2, meaning that the elastic moduli of ropes were less than half that of original fiber/wire. When new VR was loaded with 1900kgf of tension, reed length became 7.18mm longer, 115 % of its original length. Because reed of VR was shorter than TR, structural elongation became larger.

The diameter of SFR became smaller (pre-test > no passage on sheave > passed on sheave), but no significant relationship was found between the reduction of diameter and the number of fatigue cycles or residual strength. This may have resulted from the method of diameter measurement. We measured an unloaded rope sample because of the danger of cutting the rope. Fiber rope diameter usually should be measured under a regular load. Because strength decreased quickly, correlation between strength loss and diameter change would be difficult to do and would likely have measurement error.

CONCLUSIONS

The results of examinations described above showed that fatigue of guylines caused by bending was severe. To ensure safety, it is effective to inspect ropes on the top of the tower, which passes through the sheave. WR fatigue life could be established by counting wire breakage and 10% wire-breakage should be regarded as the standard for replacement. In the 6x19 WR used in this examination, wire breakage tended to occur on the surface. But many kinds of mobile tower yarders are equipped with IWRC (independent wire rope core) ropes. In this type of WR, since internal wire breakage may occur, the effectiveness of the 10% wire-breakage rule is not clear. Further work is necessary to estimate the fatigue life of IWRC rope.

Measuring the degree of damage in SFR was difficult. Since its strength decreased quickly, judging its fatigue life by fiber breakage or diameter reduction is impossible. Additionally, SFR fiber breakage is difficult to quantify and diameter reduction may contain measurement error. Since fatigue by bending and abrasion on the sheave occurred at the same time, the effect of abrasion alone on strength loss could not be evaluated. SFR is a delicate material, and the estimation of fatigue life and management of damage with an easy field measurement system is difficult. A method of safely managing SFR should be established considering the specificity of its strength loss.

The results of fatigue tests of VR and TR showed that the braiding method affects the strength of SFR much more than the material. VR short-reed rope showed faster fatigue and lower tensile strength. But short-reed rope has advantages; for example, it can retain its shape on a winding drum. The best reed length should be determined and the characteristics of fiber materials should be examined using the same reed length of rope.

The TR we examined appeared to be suitable as guylines on mobile tower yarders, judging by the number of fatigue cycle until rope breakage. Although TR costs three times as much as WR, its effect for decreasing work intensity and facilitating handling should be considered in selecting guyline ropes. Further trials of SFR guylines will be done using a real machine to evaluate its benefits on workload and handling. These factors were difficult to examine using the test machine and the use of a real machine will verify the practical use of SFR for guylines.

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Part 5

Environmentally Sound Logging Operations

Reduced Impact Wood Harvesting in the Frame of FAO-Code; A Concept for East Kalimantan, Indonesia

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ABSTRACT

Environmentally-oriented wood harvesting has developed rapidly and gained a warm welcome from different parties, including some international agreements on sustainable forest management.

Research on reduced impact harvesting with the Indonesian Selective Cutting and Planting (TPTI) system in East Kalimantan's natural tropical forest shows that reduced impact harvesting can reduce soil and residual stand damages up to 50% without significantly decreasing productivity and increasing production cost.

This document is one response on the FAO Model Code of Forest Harvesting Practice, to promote forest harvesting practices that improve standards of utilization and reduce environmental impacts, thereby contributing to the conservation of forests through their wise use.

This concept is prepared as a manual for reduced impact wood harvesting that can be used as guidelines for wood harvesting practices with the TPTI system in East Kalimantan's natural tropical forest and as a training material for the application of the manual.

KEYWORDS--*Reduced impact, code, training, harvesting*.

BACKGROUND AND PURPOSE

Environmentally-oriented wood harvesting has developed rapidly during the last few years and has received a warm welcome from different parties, particularly loggers, researchers and politicians in the forestry sector.

Several research results (Elias, 1995; Bertault, J.G. and Sist, P. 1995; Pinard et.al., 1995 and Hendrison, J. 1990) concludes that damage caused by tractor logging can be minimized by means of better harvesting planning, proper, well controlled harvesting operation techniques, and preventive measures to minimize environmental damages after harvesting.

The purpose of this concept is to have a manual for reduced impact harvesting, that can be used as guidelines for harvesting practices with the Indonesian Selective Cutting and Planting (TPTI) System in East Kalimantan's natural tropical forest. It will also be used as training material for the application of the manual.

CONTENT OF WOOD HARVESTING PLAN

After long and mid term planning of sustainable forest management is completed strategic plan, the annual operational harvesting plan (technical plan) is the next crucial planning step.

The harvesting plan is prepared in a written verbal description of the action plan and on a large scale map.

The harvesting plan shall contain at least the following items:

- Description of the harvest area/block (location, sub-block, compartments, etc.)
- Forest potential (effective areas to be harvested and not harvested, dominant species and harvestable timber volume)
- Access plan and timber transportation system
- Required harvesting equipment and activity schedule
- Post-harvest rehabilitation plan

The harvesting plan map shall include:

- The entire area (location) to be harvested, including its borders
- Contour lines (with interval 5 or 10 m)
- Existing and prospective road network
- Landing location
- Skidding road network and skidding direction
- Tree location and planned felling direction
- Wet and dry areas/locations
- Protected area
- Rivers to be used for transportation

IMPLEMENTATION GUIDELINES

The implementation steps of reduced impact harvesting are:

- Development of tree location map and contour map (scale 1:2,000) is carried out two years before cutting.
- Cutting of liana is carried out during the forest inventory and topography survey two years before cutting.
- Development of harvesting plan showing location on a contour map is carried out one year before cutting.
- Haul road construction and marking of skidding road network, landing, tree felling direction in the field is carried out one year before cutting.
- Skid trail road construction, felling, winching and skidding is carried out during the harvesting year.
- Prevention of further environmental damages is carried out after harvesting.

The strategies to reduce logging waste, increase skidding efficiency, and minimize the residual stand damages are:

- To increase efficiency of timber utilization:
  i) Undercut and backcut on trees to be harvested are made as low as possible

  ii) The stem above the first branch, stems with buttress and marketable stems as much as possible

- To increase skidding efficiency :
  i) Prevent the skidding tractor from leaving the planned skid trail

  ii) Use winch whenever possible

  iii) Avoid sharp bends in the skid trail

  iv) Adjust the volume of logs being skidded to use the capacity of the tractor

  v) Skidding direction, felling direction and the planned skid trail should be synchronized

- To improve worker skill and motivation
  i) Provide training on technical matters and environmental understanding and awareness

  ii) Apply a payment system based on quantity and quality of work
- d) Create a clear job description

FIELD IMPLEMENTATION

- In accordance with the harvesting plan map, the planned skidtrails are marked on the trees with red paint, and planned felling direction at the stump of the harvestable trees.
- Before felling, the skidtrail has to be cleared/opened by the chainsaw operator.
- Felling operation begins according to the plan.
- The number of logs bucked from a certain tree has to be recorded on the harvesting map to inform the tractor operator and his helper.
- The felling team prepares a small path from the logs to the skidtrail, in order to facilitate winching activities.
- Skidding starts by removing the trees already felled, improving and leveling the skidtrail.
- Winching and skidding operations use the harvesting plan. The helper of the tractor operator sets the choker and directs the tractor to the right place. During skidding, the tractor must not leave the prepared skidtrail.
- After skidding of logs from a certain tree is finished, the number of logs noted on the harvesting plan map is ticked off.
- After skidding is finished, the skidtrail has to be closed. Ditches, crossing the skidtrail in an angle of 45 degrees, have to be installed at a distance of 10-30 m.
- Block inspection has to take place continuously and after all wood harvesting activities in one compartment are over. The main task is, to evaluate the harvesting results and to calculate base pay and premium according to quantity and quality of the work.

CONCLUSIONS

- Reduced impact harvesting with the TPTI system in East Kalimantan's natural tropical forest can reduce damage by one-half as compared with conventional wood harvesting. It is therefore important to promote the implementation of the reduced impact harvesting with the TPTI system.
- To guarantee the success of the reduced impact harvesting implementation, it is recommended to:
  i) develop guidelines for the reduced impact harvesting with the TPTI system in tropical natural forest in East Kalimantan.

  ii) conduct training for wood harvesting planners and supervisors, chainsaw operators, tractor operators and felling and skidding foremen.

  iii) encourage further research on reduced environmental impacts in tropical natural forests while simultaneously improving productivity and reducing harvesting cost.

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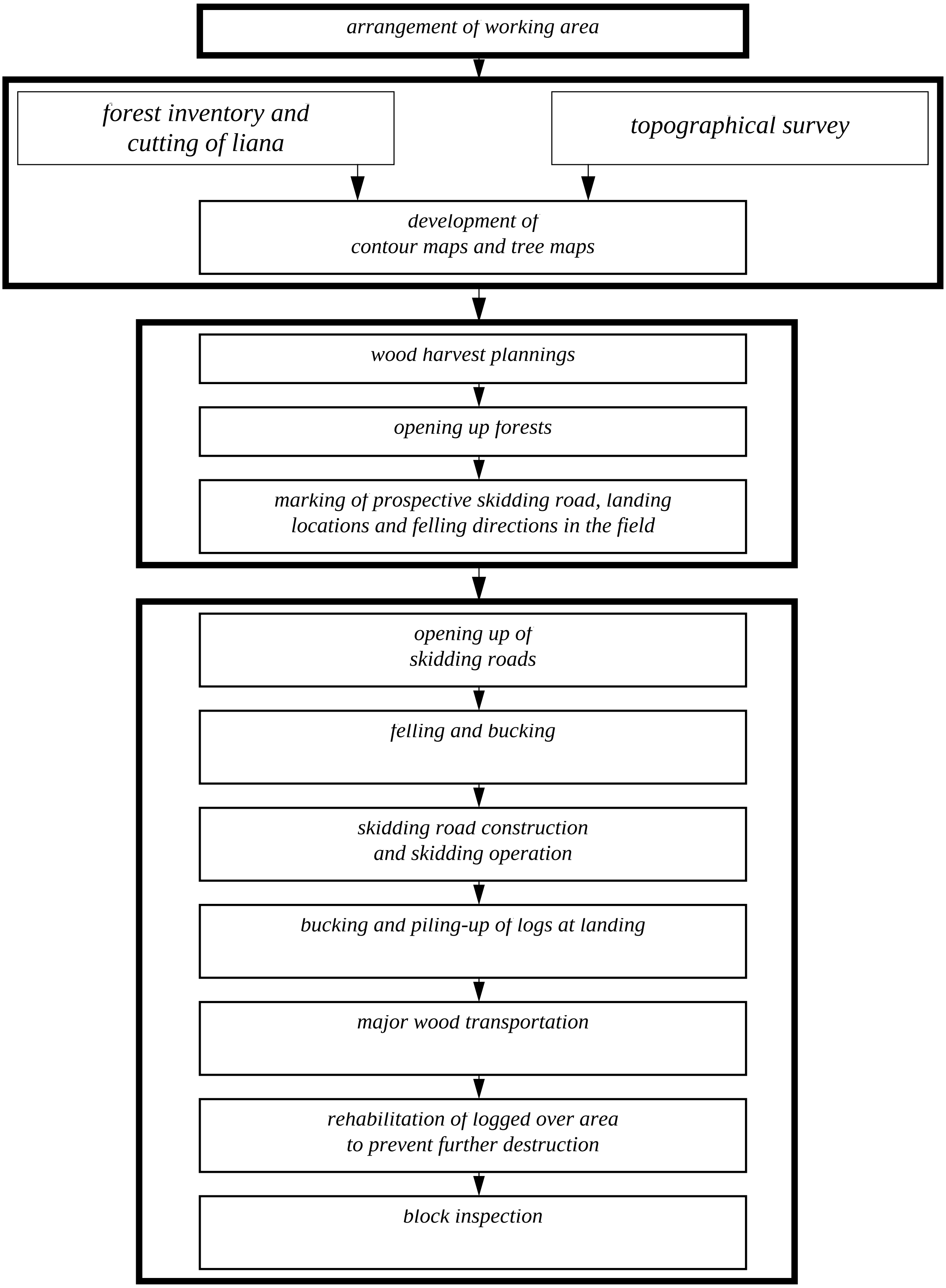
Annex 1

Flow diagram of reduced impact wood harvesting with regard to the TPTI stage



Implementation of Forest Machines - an Ecological Disaster?

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ABSTRACT

Concepts of forestry practice, which aim at a sustainable use of land, are considered less and less satisfactory if they merely separate unrestrictedly managed areas from reservation areas. The quality of logging techniques must be high, but very often, the employment of machines is on principle regarded critically. The Central European view of "naturalistic forest management" is outlined on the basis of a literature study as an example.

The terms "immission", "impact", and "ecological damage" are discussed, and damage is interpreted as a function of ecological effect and a value system. Looking at individual forestry measures, environmental aspects of some techniques are compared. A distinction is made between the consumption of resources (materials, energy) associated directly with a technique, and the effects of the employment of machinery on the forest.

The risk involved in any measure undertaken comes, among other things, from the damage potential, the length of the recovery phase after a disturbance, and the probability of technical error, in combination with the so-called human factor.

From this way of looking at things, conclusions are drawn for the use of machines in the forest. It is shown how fields for employment of forest techniques can be derived as "environmentally friendly niches".

The weight of philosophy and psychology in the evaluation of a technique is high in comparison to purely scientific or economic factors.

KEYWORDS--*Forest techniques, ecology, sustainable development, machines, forestry*

INTRODUCTION

The use of harvesting machines in forests is seen very critical by many people. Foresters also belong to this group. Nature conservation groups would prefer big forest machines to be forbidden. The criteria shown in table 1 characterise the understanding and the discussion of nature oriented forestry in Central Europe. They were collected in an analysis of programmes of nature conservation groups like Greenpeace Germany, silvicultural guidelines of forest administrations and articles of scientists. The analysis is described by Pausch and Röder (1997).

Demands like “single tree harvesting”, “small scale cutting only”, “mixed, unevenaged stands”, “high dimensions”, “no clearcut”, affect forest techniques directly.

Reservations are caused by the fear that the demanded stand structures and tending methods are not compatible with big machines. Besides this, ethical and philosophical arguments can be found. For example, people observing a harvester for the first time consider the short time needed for processing a tree grown over one hundred years to be a disregard of nature.

The following is an attempt to get a short view of ecological aspects connected with the employment of forest machines.

IMPACT AND DAMAGE

Immission is considered to cause damage, if an observer perceives the effect as inconvenient or suffers from a decline in value. The satisfaction of bare necessities can be affected as well as visual, psychological and social values. The consequence of harmful immissions is a loss of resources. In a long term view, it is difficult to separate economical from ecological damage. To relieve one individual of a negative influence can increase other damage. A social value system provides the framework for the necessary decisions. Damage can be seen as a function of the impact of an immission and a value system.

Here we have the connection to the adjacent area of religion and philosophy. If an individual becomes aware of a damage for other life, it can turn out to be a loss of values and a cause of pain or damage for the realising individual itself.

According to the definition above, damage also includes the suffering of future generations. The total damage is the sum of all damages individually felt. Therefore, the future effects of a damage can contribute to large quantities when lasting for a long period - even if it seems to be a small problem at the moment. A good example is soil degradation.

The degree, to which an impact can be healed, very essentially defines the level of a damage. It is easy not to take into account the full future damage or to regard it as less serious. But this attitude is more and more considered dissatisfactory or even objectionable. The discussions about certification and harvesting practice codes can be taken as

Objectives	**Stand structure**	**Stand treatment**	**techniques**
- biodiversity	- mixed	- single tree management	- protection of stand, soil, landscape, environment
- protection of species, habitats, processes	- oriented to natural vegetation	- long term, natural regeneration	- priority of silvicultural concepts
- ecological stability	- natural regeneration	- utilisation of natural processes ("biological rationalisation")	- restrictions on big machines
- sustainable timber supply	- uneven aged, stratified	- high cutting age	- final opening up with skid tracks
- high timber quality	- old, large trees	- clearcuts avoided	- soil cultivation avoided
- economy	- high timber quality		- strict limitations on biocides, fertilizers
	- minimum amount of dead wood		

TABLE 1. Criteria of naturalistic forest management.

evidence. In detail, it is a difficult question how far to accept postponing damages into the future in order to avoid other damages by the means that are becoming free.

Nowadays the basic forest definition of sustainability is a part of the comprehensive aim of sustainable development, as it was set up by the Rio conference.

To discuss the question raised in the title the variants of forest techniques available have to be investigated under aspects that are ecologically important. In the following this is done only with some examples of harvesting operations in forestry to show tendencies and basic correlations. Of course, a comparison to other forms of utilisation of environment would be necessary, which is not included in this paper.

ECOLOGICAL EFFECTS OF FOREST TECHNIQUES

Machine mass "consumption"

The material consumption per unit of timber harvested can be derived from the amount of materials needed for construction and maintenance of a machine, the machine life, the average productivity and possibilities for recycling. To give an idea of the material consumption, Figure 1 shows an estimation of machine masses per cubic meter of timber for a chainsaw, a processor attached to a tractor, and a harvester. An exact calculation requires the method of life cycle analysis LCA.

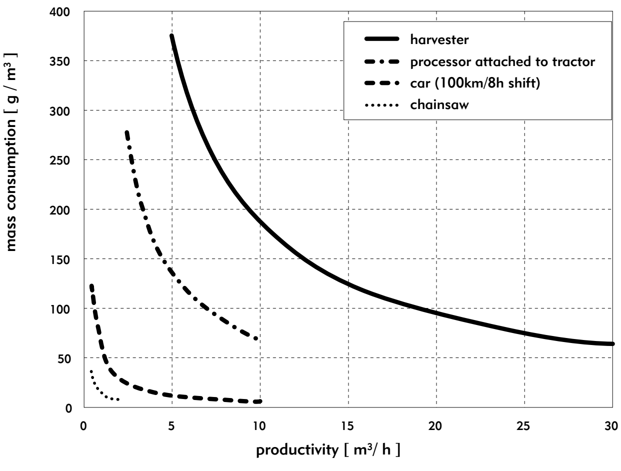

FIGURE 1. "Machine mass consumption" per unit of harvested timber.

The consumption of materials for the processes of construction and maintenance of forest road networks is not taken into consideration. The calculation of the chainsaw includes replacement of the bar and the chain. The values are based on test reports of the ZFP (1989, 1990). A precondition for this calculation is, that the machines are stressed according to their construction.

Consumption of chain oil

As an example, chain oil consumption is estimated by means of consumption values of test reports (ZfP, 1989, 1990). It is supposed to be proportional to the time required per cubic meter (Figure 2). Bojanin (1997) specifies consumption values for high DBH`s, which lay in the same range.

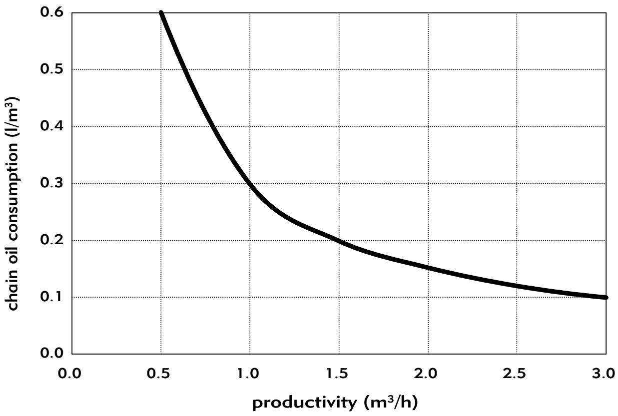

FIGURE 2. Chain oil consumption per unit of harvested timber.

Fuel consumpiton

The fuel consumption of a Timberjack 1270 single grip harvester was measured in a test of the Eco-Mate system of Lars Bruun this year. It is strictly correlated to the cycletime (Fig. 3). The curve of the chainsaw is computed as pointed out above.

Under easy conditions (high productivity), the fuel consumption of the harvester comes very close to that of the chainsaw. Small-sized wood and high driving times cause high specific consumption.

Energy consumption

The energy consumption of different forest techniques (Figure 4) can be compared by equivalent heating values (fuel consumption of the chainsaw: ZFP (1989, 1990); harvester: results of the ecomate experiment at our institute (Scharf, Bollin, Pausch, Feller, 1997); values of embodied energy (Löffler 1991); fuel consumption of

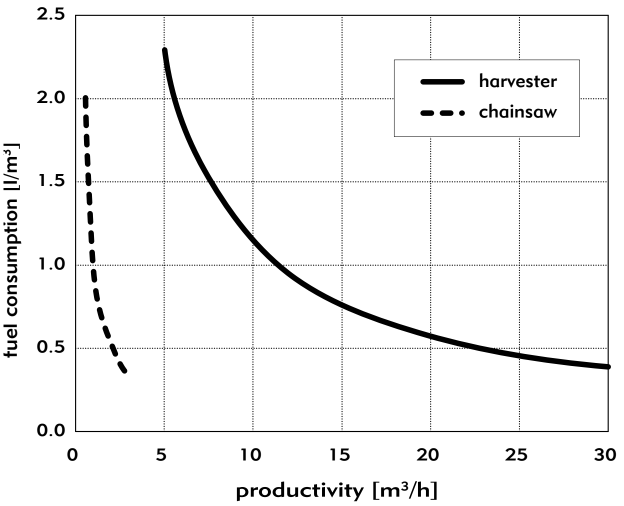

FIGURE 3. Fuel consumption per unit of harvested timber.

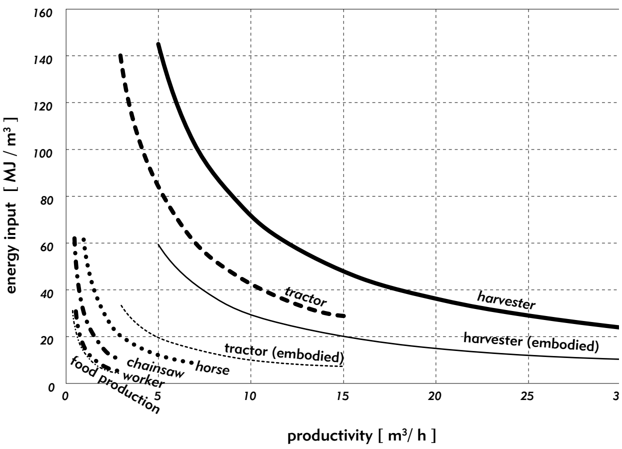

FIGURE 4. Consumption of process and embodied energy per unit of harvested timber for different harvesting methods.

construction machines (BUWAL, 1994). The energy consumption caused by transport of machines or the car of the operator is not included.

To decide between alternatives of employment, the energy consumption of a forest worker has to be taken into account as ecological opportunity costs. The daily consumption is supposed to be 18 000 kJ/24 h for eight hours work per day at the limit of sustained work performance (Löffler, 1992). The energy consumed by the production process of the food is assumed to be five fold this value. It is derived from a figure given in Weizsäcker (1996), which shows the "ecological burden" of different kinds of food. For the USA, the indicated factor is 10.

The data for the skidding horse are calculated as the heating value of the food consumption per year (empirical values, taken from different sources).

Low mechanised systems seem to be better in the comparison discussed above. But there are overlappings. Furthermore, the energy input of a tractor is almost equal to that of a harvester. Therefore, the employment of a tractor also means high mechanisation.

It seems that heavier harvesting machines do not compensate the higher conversion of material by higher production. But a realistic comparison requires the investigation of a whole harvesting system.

If the same distance of skid trails of e.g. 20 m is used, it will cause similar material consumption for the extraction by a forwarder for both a harvester and a motor manual method. It can be expected that the chainsaw will come out better in this case. If the timber has to be hauled to the trail by a tractor winch, the productivity will drop. This could lead to equal results for both variations.

To decide between varying harvesting methods, the consumption of raw materials has to be calculated for each individual operation. In the case of low productivity, e.g. in stands with small sized timber, high mechanised systems quickly reach a high level of consumption.

Energy consumption of road infrastructure

As an example, the fuel and energy consumption for the construction of 100 m road under mountainous conditions is roughly estimated on the basis of empirical values in the Bavarian state forest. The consumption rate is refered to the amount of timber harvested. The area opened up, the stand growth and the lifespan of a road has to be taken into account.

Figure 5 shows a comparison between a harvesting system consisting of road construction, motor manual logging, yarding by mobil tower yarder, tractor skidding and an alternative based on helicopter-logging. Helicopter data were taken from Boswell (1996). In the last case, it is supposed that only a fifth of the road length is necessary and that the timber along the road (40 %) is yarded by a cable crane as described above.

In this calculation, the employment of a helicopter is suitable for a situation with an amount of timber harvested less than about approximately 250 cubic meters. Unproductive, inaccessible areas or short lifespan of forest roads because of geological or climatic factors characterise an "ecological niche" for a helicopter. Outside these narrow borders, the energy consumption of the helicopter variation obviously turns out to be greater than the first variation.

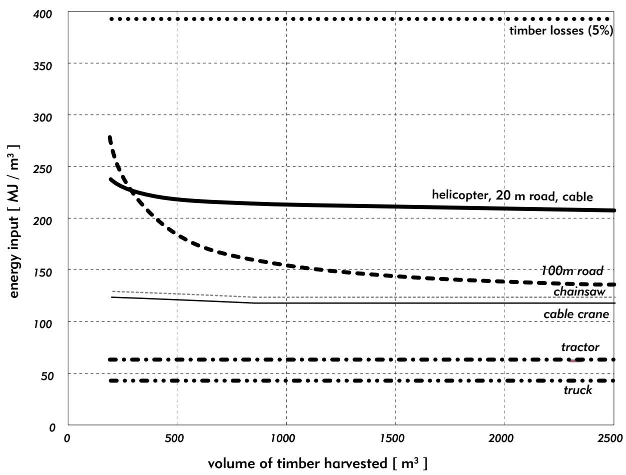

FIGURE 5. Input of process and embodied energy for different harvesting methods.

Even small differences in the amount of timber losses are of great importance for the energy balance (Wegener et al., 1997; Frühwald et al., 1996). To explain this, the energy equivalent of a 5% timber loss is drawn in figure 5. It exceeds the fuel consumption of the machines. High timber losses caused by log driving and floating are examples for low mechanised methods with unfavourable energy balance.

The discussion about machine employment very often disregards transport processes. But a large amount of material and energy consumption seems to be hidden in transport. Also the damages to the stand and to the soil depend for a great part on the hauling methods.

IMPACTS OF MACHINES ON THE FOREST

Stand damages

Harvesting methods using single grip harvesters usually cause less damage than motor manual operations (Bort et al., 1993). These machines are also suitable for thinnings in broad leaved stands (Guglhör, 1994).

Depending on the tree species, the probability of injuries of the undergrowth increases in old forests because the crane has to draw heavy trees to the trail with all branches (results of an trial in 1995).

Conventional wheeled harvesters reach their technical limits in stands with heavy timber. Experiments with modified tracked excavators showed a remarkable low level of damages to the stand, especially to the regeneration (Weixler et al., 1997). To a certain degree, it may be difficult to prove that such damages have negative effects on the biological potential. New habitats created by damages may even turn out to be advantageous for some species.

But a loss of wood-resources has to be taken into consideration - comparable to the discussion about dead wood to be left in stands. From this point of view, a loss of wood-resources is acceptable only to that degree, which minimises the ecological damage as a whole. This level has to be related to the scale of the necessary potential. The decision on remarkable higher losses of wood-resources is ethical or political.

Indirect impacts on the stand structure

The shorter the processing time, the higher the influence of driving time on productivity will be. Because of technical limits, the performance of harvesting machines normally decreases above a certain tree dimension. This has as a consequence that cutting of only some individual heavy trees per hectare by a specialised machine will lead to lower productivity than in the case of cutting a higher number of medium-sized trees.

If the application of a technical system leads to a silvicultural concept that causes clear deviations from the structure of natural forest areas, an ecological damage through losses of natural resources will be registered.

To this wide area only a few comments. One can separate biological long term and economical damage. The risk is positively correlated to the specific soil pressure of the machines used (Matthies et al., 1995). The discussion of threshold values is not yet finished. Soil compaction or erosion can be measured quite well. The question, how soil damages affect flora and fauna is not yet answered satisfactorily.

Conditions with a low level of soil moisture are suitable for machine operations. In practice, the pressure to fully utilise machines or time pressure caused by planning mistakes lead to machine employment under unfavourable conditions. Disasterous damages occur quickly.

ECOLOGICAL RISK AND FOREST TECHNIQUES

Several means are introduced in forestry to increase safety for the workforce. Examples are safety clothing and the chain brake. It is important that these measures are designed according to the danger potential and that handling mistakes are taken into account.

Transferred to forest machines, one could imagine a break that stops the machine when leaving the skid trail or position indicators and automatic device to control the crane and machine movement in a stand. But already the design of machines (weight, technical principles etc.) must avoid damage potential.

Central factors which define a damage potential are the frequency of mistakes, the probability of the "worst case" and the time needed for regeneration.

HOW TO SELECT SUITABLE FOREST TECHNIQUES

In the selection of suitable forest techniques, a first step is to use filters for general environmental requirements on fuel consumption, noxious emissions and noise reduction as well as on tyre equipment, construction of undercarriage and probability of handling mistakes.

After that, filters have to be passed which control the employment of the technique according to the terrain, the soil factors, the stand structure, the cutting method and, last but not least, the required skills of the operator.

This filter system is multidimensional. Consequently, the width of mesh is influenced by interferences between the variables and the factors.

A forest machine has found its "ecological habitat" after passing through such filters. Otherwise, an ecological disaster is possible.

The question, whether the implementation of forest machines is an ecological disaster, cannot be answered in general. The degree of damages caused by harvesting operations depends on the forest mindness and motivation of the workforce. Ultimately, the final decision is influenced by the value system of the observer.

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Manual Versus Power Chain Saw In Bhutan

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ABSTRACT

In the steep terrain conditions of Bhutan forest work is very heavy and hazardous, too. Compared with other industries working in forestry is much more dangerous and physically extremely heavy. Therefore jobs in forestry are unattractive. There is a need to improve the work conditions by introducing better logging tools and by adapting and developing appropriate working methods. The paper presents results of a study of felling operations comparing cross cut saw with power saw.

In Bhutan four methods are common for felling trees: using axes, bow saws, cross cut saws, and power saws. In the study felling 84 trees with cross cut saw was investigated because up to now no figures were available. The resulting productivity was 2.5 m3 per hour. Power saw productivity was estimated to be three times higher. The calculation of unit costs per cubic meter does not result in significant differences between cross cut saw and power saw felling. Therefore cross cut saws should be promoted whenever labour force is available.

KEYWORDS-- *Manual felling, cross cut saw, power saw, productivity.*

INTRODUCTION

Forestry operations, particularly harvesting involve very heavy physical work and is hazardous compared to many other industries. This is particularly true in Bhutan where the terrain is rugged and the slopes are steep making logging operations very difficult and unattractive. The workers come for logging job only when no other job is available to them. Therefore, to make it attractive and less difficult, it is necessary that appropriate studies on logging technology be carried out so that the methods and tools are ergonomically suitable as well as economically viable.

It is assumed that since the body weight of a Bhutanese worker is less than the weight of a European, his ability to perform heavy muscle work is consequently less than that of a European. Therefore, the logging tools which are suitable in Europe may not be very practical in Bhutan. It is thus very necessary that the methods and tools should be used with proper studies with regard to their suitability under the Bhutanese condition.

This paper basically presents the production efficiency and the costs involved for coniferous forest using manual techniques as well as power chain saw. However, observations and conclusions presented in this paper are not based on a huge database and critical scientific analysis. Some assumptions also have been built in based on long term personal experiences in forestry.

CHOICE OF ALTERNATIVE METHODS

In the light of the above, appropriate tools for felling trees in the Bhutanese conditions are: (1) Axe, (2) Bow Saw, (3) Two-man cross cut saw, and (4) Power chain saw.

Axe

The size and design of axes should depend on their purpose, that is, on tree size and on the body weight and strength of the worker. For these reasons axe models are highly variable from one application to another.

Axes are generally used for felling, debranching and splitting firewood. In Bhutan, felling by axe is discouraged because of high timber wastage, poor efficiency and high energy consumption. However in rural areas axes are still the widely used tool for felling and cross cutting because they are readily available, easy to use and do not require expensive maintenance.

Bow saw

There has been no study on its efficiency so far. But it could be a very appropriate method for felling smaller trees with diameter less than 30 cm. Usually in plantation thinning.

Two-man cross cut saw

Improved types of cross-cut saws were introduced in Bhutan in 1975 and training on its maintenance and uses also conducted in the logging centre under the Forest Department. The standard length of these saws are usually 1.5 m and are used for felling bigger diameter trees. Two types of these saws are available - Peg Toothed saw and Raker Toothed saw. The choice between the two is determined by the skill in maintenance. The Raker toothed saw demands more working skill, accuracy and special maintenance tools. If these facilities are not available, the peg toothed saw is the better practical alternative. The maintenance cost of these saws are very much less than that of the power chain saws. It is labor intensive and yields higher production than an axe.

Power chain saw

In large forestry operations, the manual methods suffer as a productive technique because of the low output even if unit costs are favorable. Capital intensive methods on the other hand yield high rates of production. Power chain saws of different makes and models have been brought into the country by the various donor agencies since 1974. Importing of the power chain saw by the general public has increased since 1985 when the forest harvesting operations were contracted out.

On the ergonomic aspect it is no doubt that mechanization increases productivity and decreases human effort. But it also adversely effects the workers' health due to excessive noise level, vibration and accidents. By far the largest number of logging accidents occuring annually are associated with chainsaws (Dykstra D.P et. al. 1996). Therefore, mechanization demands training and additional safety measures. However, so far there is no well defined statistics on the ergonomic situation in Bhutanese forestry.

METHODOLOGY

Study on the efficiency of the two-man cross cut saw was carried out for the conifer forest by then the Chelaila Logging Centre. The results were as follows:

Production

Two-man cross cut saw:

trees (no)	**Out-put** (m3)	**Time taken** (days)	**Produc-tion** (m3/day)	**working time** (5h/day)	**Production** (m3/h)
84	187.3	15	12.49	5	2.5

TABLE 1. **Table showing production in conifer forest with the two-man cross cut saw.**

Power chain saw:

Based on the past experience, it is assumed that the productivity of the power chain saw is about 3 times higher than that of the two-man cross cut saw. Therefore, the productivity can be projected to be approximately 7.4m^3/hour.

Cost

The cost of forest operations consists of labor cost plus machine cost. Machine cost includes machine acquisition, interest cost, repair maintenance cost and operation cost. From the perspective of maximum economy an appropriate technology is one which has a low combined labor and machine cost.

Unit cost comparison between the two-man cross cut saw and the power chain saw was also carried out and summarized below:

Cost per hour

Sl.No	**Cost component**	**Power chain saw (Cost/ hour: Nu)**	**Two-man cross cut saw (Cost/ hour: Nu)**
1	Fixed cost	20.47	0.29
2	Variable cost	74.00	0.42
3	Labor cost	32.40	40.32
	Total	126.87	41.03

TABLE 2. **Table showing the comparison of cost per hour between power chain saw and two-man cross cut saw.**

Cost per cubic meter (m^3)

Sl.No	**Method**	**Output per hour (m^3/ hour)**	**Cost per hour (Nu/ hour)**	**Cost per m^3**
1	Power chain saw	7.4 m^3	126.87	17.14
2	Two-man cross cut saw	2.5 m^3	41.03	16.41

TABLE 3. **Table showing the comparison of cost per cubic meter between the power chain saw and two-man cross cut saw.**

CONCLUSIONS

The following conclusions can be drawn from the above.

1. Axe yields less production and more wastage than the two-man cross cut saws.
2. Although the production with power chain saw is 3 times greater than the two-man cross cut saw, the unit cost does not differ significantly (Table 3).
3. No well defined statistics exist on the ergonomic situation in Bhutanese forestry

RECOMMENDATIONS

1. Two-man cross cut saws should be encouraged and introduced in the rural areas.
2. Where there is labor availability, two-man cross cut saws should be encouraged and where there is no labor availability the power chain saw should be used.
3. Since there is hardly any information on ergonomic status, it should be developed and practiced in the future.

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Part 6

Ergonomics

Some Ergonomic Evaluations of Industrial Forest Plantation Workers in East Kalimantan

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ABSTRACT

This paper summarizes research on ergonomic evaluations of industrial forest plantation work being carried out in East Kalimantan. It presents findings from several types of work, such as felling and cutting, weeding, spreading fertilizer, road maintenance, path clearing, soil hoeing and planting, by using several ergonomic evaluations (i.e., thermal conditions, heart rates and fatigue symptoms tests). The observation of thermal conditions showed that the temperature was 37.4˚C at three o'clock and global temperature was 52.3˚C at that time, which were considered as very severe conditions. The observation of heart rate showed that path clearing and soil hoeing were found to be harder work in terms of energy consumption. The results of the cumulative fatigue symptom research indicated that people who migrated earlier are more physically fatigued than those who migrated later. In conclusion, we recommend that shelters should be made for workers to take a rest, avoiding intense sunlight, and that forestry work should be carried out in cooler areas during heat peaks.

KEYWORDS--*Industrial forest plantation, thermal conditions, physiological loads, fatigue symptoms, working time design.*

INTRODUCTION

Tropical rain forests in Kalimantan are one of the most important natural resources in Indonesia. Valuable timbers have been used for several decades for the benefit and prosperity of the people. Tropical rain forests in East Kalimantan cover an area of 17.3 million ha or 82% of the whole area. To compensate for the decrease of wood potential that was caused by logging activities, the Indonesian government, since 1984, has had a policy to establish industrial forest plantations. In 1990, the project of transmigration for industrial forest plantations in East Kalimantan was suggested to some forest companies by the government. East Kalimantan was selected as a destination of transmigration because of its thin population. The environmental conditions and situations in East Kalimantan are becoming a problem for forestry workers who come from Java. Kalimantan has very severe thermal and environmental conditions. Because it is located on the equator while Java is relatively far from the equator and has a relatively lower temperature (Figure 1). The form

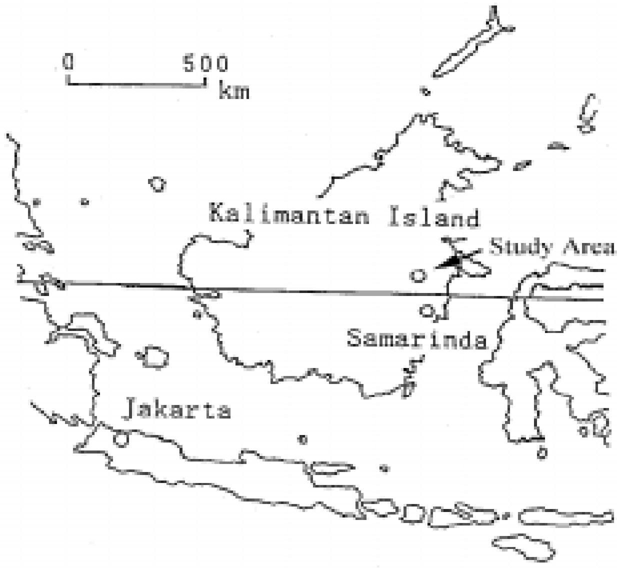

FIGURE 1. Study area.

and nature of industrial forest plantation work are also different from agricultural work which transmigrants used to do. Because such forestry work is done continually in various kinds of forests, under the supervision of forest companies, while agricultural work is done periodically and they have a longer time to take a rest and do other social or economic activities. The industrial forest plantation is a new project in Indonesia and the above-mentioned problems must be solved to better the lives of the people. This paper describes some ergonomic evaluations of forestry work carried out in East Kalimantan focusing on industrial forest plantation work and workers from 1993 to 1996. The main objectives of this research are to clarify working conditions, physiological loads and fatigue of industrial forest plantation workers in order to suggest proper work and work time schedule.

METHODS

Observation of Thermal Conditions

In this research, we observed temperature, humidity and global temperature during various types of work at different locations: including felling and cutting trees, weeding in the forests, spreading fertilizer at the nursery, road maintenance, path clearing using a chain saw, soil hoeing and planting at logged-over areas. They were measured every 30 minutes at each location from 7:00 to 16:00. Measurements were repeated three times at each location and locations were chosen at random. To observe global temperature, we used a large globe thermometer. In direct sunlight, the WBGT can be calculated by the equation below (Rohles et al., 1987):

$$WBGT = 0.7NWB + 0.2GT + 0.1DB \qquad (1)$$

where, WBGT is Wet Bulb Globe Temperature (˚C); NWB is Natural Wet Bulb Temperature (˚C) on exposure to natural air currents; GT is Globe Temperature (˚C) measured using a black globe thermometer with a diameter of six inches; DB is Dry Bulb Temperature (˚C) on exposure to natural air currents while being protected against radiation heat sources.

Measurement of Physiological Loads

The forestry workers were equipped with heart rate memory devices, and their heart rates were measured every 10 seconds automatically. In advance, we carried out a step test for each worker to evaluate heart response and make regression models between step test and heart rates. By using these regression models, heart rates during working time were converted to physical work. In this process, the equation below (Hirakawa, 1983) was used and the energy metabolism was estimated.

$$Eg = 0.0163 \times W \times N \times H + 1.2Bm \qquad (2)$$

where Eg is the energy metabolism (kcal/min); W is the weight of a worker (kg); H is the height of step test platform (m); N is stepping rate (times/min); Bm is basal metabolism (kcal/min). We converted kcal to kilojoule by multiplying values in kcal by 4.2.

Measurements of Fatigue Symptoms

The cumulative fatigue symptom research is the method to find occupational or living factors that make a negative impact on workers' health. This research employs a questionnaire method, which gives yes or no questions regarding 76 items of the cumulative fatigue symptoms index (CFSI). The reliability of this method is certified in the former research (Kosugo, 1991). These items are separated into groups such as NF1, NF2-1, NF2-2, NF3, NF4, NF5-1, NF5-2 and NF6. NF1 consists of 9 items related to power loss; NF2-1 consists of 10 items related to general feeling of fatigue; NF2-2 consists of 9 items related to physical disorder; NF3 consists of 7 items related to irritation; NF4 consists of 13 items related to loss of will to work; NF5-1 consists of 11 items related to feeling of uneasiness; NF5-2 consists of 9 items related to feeling of pressure; NF6 consists of 8 items related to chronic fatigue.

Method of Working Time Design

In Sweden, shift systems and job rotation systems are used in a mechanized thinning operations (Nabo, 1991). To introduce this kind of system to the industrial forest plantations in East Kalimantan we first defined the structure of working time by dividing a day into five sections (i.e., early morning from 7:00 to 9:00, morning from 9:00 to 11:30, midday break from 11:30 to 12:30, early afternoon from 12:30 to 14:00 and afternoon 14:00-16:00). Applying the standards of the American Conference of Governmental Industrial Hygienists (ACGIH) (Miura, 1974), the proper working time design for a tropical forestry operation was determined based on thermal and physiological data.

RESULTS

Thermal Conditions

Thermal conditions observed in the four areas are shown in Figure 3(A)-(E). According to these figures, the WBGT is the highest at logged-over areas and reaches its height at 32.2˚C at 12:30. At the nursery, the WBGT is also high, but a little lower than that at logged-over areas. There, the WBGT is 23.7˚C at 7:00 and continuously increases to 30.4˚C at 12:30. On the road, the highest WBGT is 32.0˚C at 15:00. On the other hand, the WBGT observed in the forests is relatively lower compared with that in the other places considered. There, the highest temperature is just 28.5˚C at 13:30. Forests are covered with canopies, which provide very good shade for forestry workers.

Physiological Loads

According to the scale of Christensen (Staudt, 1993), the work load for path clearing by the use of a chain saw is an average of 57.5 kJ/min and is highest among the work classifications. This work could be classified as extremely heavy work. Soil hoeing averaged 42.7 kJ/min; such work may be classified as very heavy work. Felling and cutting trees and weeding averages 37.0 kJ/min and 32.4 kJ/min, respectively; these tasks are classified as heavy work. Planting and road maintenance averaged 26.4 kJ/min and 29.1 kJ/min, respectively, and these tasks are classified as moderate work. Spreading fertilizer averages 16.8 kJ/min and is classified as light work.

Fatigue Symptoms

Figure 2 shows the results of the cumulative fatigue symptoms research. In this figure, HTISP1 and HTISP3 are the

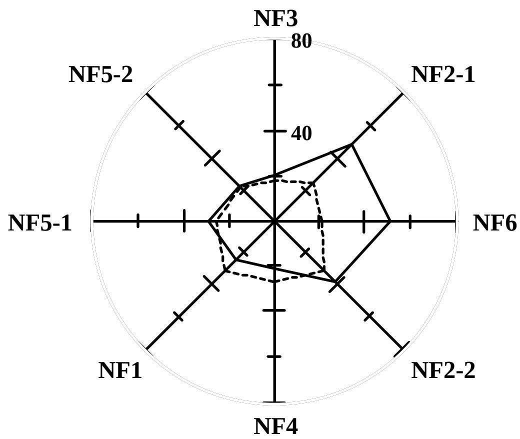

FIGURE 2. Results of cumulative fatigue symptoms research according to longtime of living.
——— HTISP1 - - - - - HTISP3

names of transmigration villages, and HTISP1 is established earlier than HTISP3. This figure indicates that the rates of responses of HTISP1 are higher in the right part that includes NF2-1, NF6 and NF2-2, than in the left part, that includes NF1, NF5-1 and NF5-2. In this figure, the right part means physical fatigue and the left means psychological fatigue. That is to say, the people who migrated earlier are more physically fatigued than those who migrated later.

Working Time Design

We established the proper working time design for a tropical forestry operation based on thermal and physiological data. According to the standards of the ACGIH, felling and cutting trees or weeding (Figure 3) could be done continuously early in the morning and required 25% rest after that time. At logged-over areas path clearing by a chain saw and soil hoeing (Figure 4) required 50% rest early in the morning and 75%-100% rest after that time. Planting at logged-over areas (Figure 5) required 25% rest early in the morning and required 50%-100% rest after that time. Planting required the least proportion of rest compared with the other types of work at logged-over areas because the workload of planting is 26.4 kJ/min, which is relatively lower than that of the other tasks. However, all forestry work at logged-over areas required more rest time than tasks at other areas. At the nursery, spreading fertilizer (Figure 6) could be done almost continuously all day.

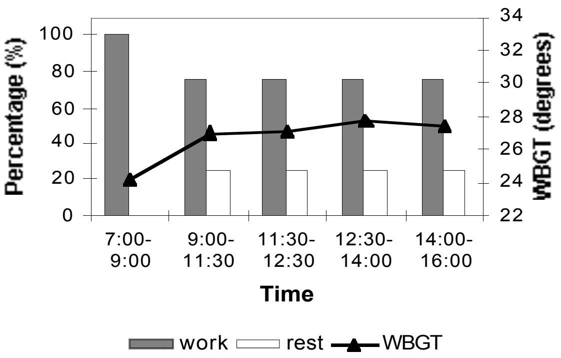

FIGURE 3. Distribution of work and rest for felling and cutting.

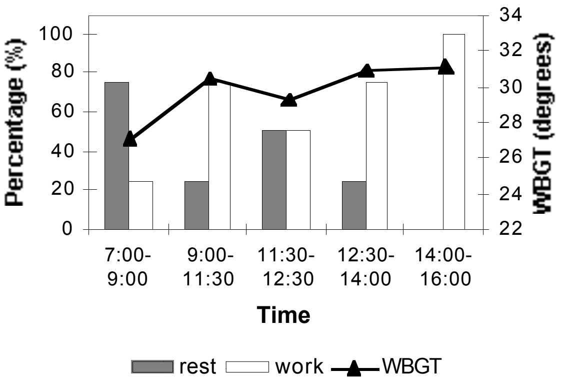

FIGURE 4. Distribution of work and rest for clearing and soil hoeing.

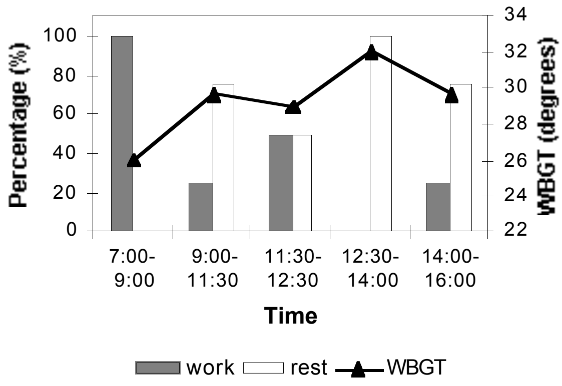

FIGURE 5. Distribution of work and rest for planting at logged-over areas.

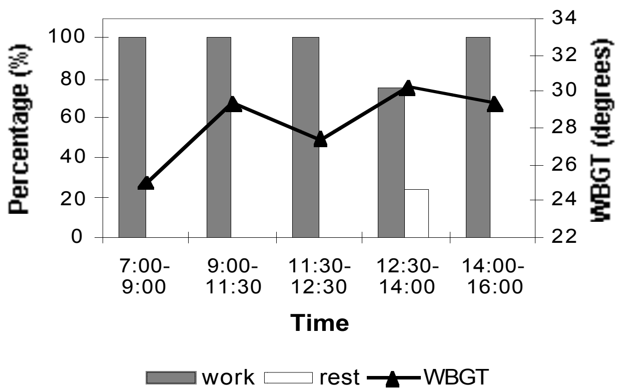

FIGURE 6. Distribution of rest and work for fertilizer spreading.

Road maintenance (Figure 7) could be done continuously early in the morning but required 50%-100% rest after that time.

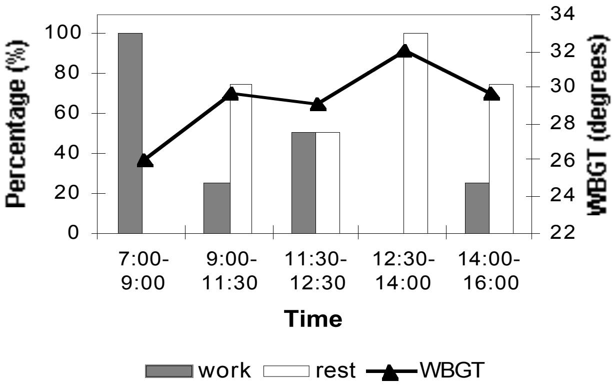

FIGURE 7. **Ditstribution of work and rest for road maintenance.**

CONCLUSIONS

Forestry work in East Kalimantan is carried out under very severe circumstances judging from its thermal conditions. These conditions are intensified when work is done in direct sunlight in the afternoon. Therefore, we clarified the working conditions, the physiological loads of forestry workers and fatigue symptoms and established the proper work time design for a tropical forestry operation. In conclusion, all forestry work at logged-over areas required more rest time than work in other areas except during early morning. Moreover, physical fatigue was higher when transmigrants lived longer in East Kalimantan. To improve working conditions, we suggest that working time should be designed according to work intensity and working conditions and that it is necessary to construct shelters, under which forestry workers can rest to avoid intense sunlight.

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Questionnaire On The Safety Of Mobile Tower-yarder Operations

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ABSTRACT

Recently, yarding operations using a mobile tower-yarder have been gaining in popularity in Japan. The use of mobile tower-yarders is expected to become a useful logging method in this country which has many mountainous forests. However the author believes that studies on worker safety must be conducted before timber harvesting can be done with these new machines.

The aims of this study are to investigate the current status of mobile tower-yarder operations and to obtain basic information to prevent worker accidents. The author investigated actual operations, near-accidents, and safety evaluations in mobile tower-yarder operations through questionnaires. These were administered to forestry workers engaged in mobile tower-yarder operations, such as tower-yarder operators, choker setters, unhookers and processor operators. There were a total of 70 respondents to the questionnaire.

The results of the questionnaires were as follows: About 71% of the yarding sites were being logged with some type of non-standing skyline cable method, especially running skyline. Most cable spans at the yarding sites were under 150m in length. 60% of the respondents had experienced near-accidents in the operations, many of which had occurred in the choker setting and the lateral yarding. A lot of workers considered the downhill yarding to be more dangerous than the uphill yarding. The author concluded that the amount of forestry work experience, worker age and the cable yarding method influenced the occurrence of near-accidents.

KEYWORDS--*Mobile tower-yarder operation, near-accident, safety*

INTRODUCTION

Mobile tower-yarders have been used for several years in Japan. According to an investigation by the Forestry Agency, there were only 3 mobile tower-yarders in operation in 1989, but by 1995, this number had increased to 144. With this increase has come the publication of studies on efficiency and yarding systems for mobile tower-yarding operations (Kobayashi et al. 1992, Tobioka et al. 1993). The author has published a report on near-accident analysis of the logging operations with multi-functional forestry machines such as processors, harvesters, tower yarders and so on (Imatomi, 1995). But there have been only a few studies on the safety of mobile tower-yarder operations.

Therefore, the author administered questionnaires on the safety of mobile tower-yarder operations, to obtain basic material to prevent worker accidents.

METHODS

The author sent questionnaires to forestry enterprises, such as logging companies and forest owners' associations, which have mobile tower-yarders. The forestry workers engaged in mobile tower-yarder operations, such as tower-yarder operators, choker setters and chasers, filled out the questionnaires themselves. The contents of the questionnaires concerned actual operations, near-accidents, safety evaluations and so on. The number of respondents was 70.

RESULTS AND DISCUSSION

Attributes of Respondents

The types of forestry related businesses represented by the respondents, and the proportion of respondents working for each type, were as follows: forest owners' association, 62.9%; logging company, 20%; forestry company (public and private investment), 11.4%; and cooperative logging association, 5.7%. The age levels of respondents were as follows: twenties, 32.9%; thirties, 20%; forties, 30%; fifties, 11.4%; and sixties, 5.7%.

The positions of respondents were tower-yarder operator (34.2%), chokersetter (22.9%), chaser (5.7%), processor operator (8.6%) and other (28.6%).

Current State of Mobile Tower-Yarder Operations

Table 1 shows the frequency distributions of the cable yarding methods, the cable span lengths and the yarding directions. The non-skyline cable method is used at many yarding sites. The cable span length mostly ranges from 100 to 150m. About 71% of yarding sites set up short spans under 150m, but there are a few yarding sites with long cable spans over 300m.

Items	Categories	Ratio (%)
Cable yarding methods	Non-skyline method	70.8
	Skyline method	29.2
Cable span length	50m - 100m	20.8
	100m - 150m	50.0
	150m - 200m	8.3
	200m - 250m	8.3
	250m - 300m	4.2
	300m - 350m	0.0
	350m - 400m	4.2
	> 400m	4.2
Frequencies of yarding directions	uphill > downhill	30.0
	downhill > uphill	35.7
	uphill = downhill	34.3

TABLE 1. **Frequency distribution of cable yarding methods, span length and yarding directions.**

About 60% of the respondents had experienced a near-accident during operations. In terms of frequency of near-accidents, "one or two times" was 66.7%, "occasional" was 21.4%, and "frequent" was 11.9%. About 70% of the respondents considered downhill yarding to be more dangerous than uphill yarding. Considering that the amount of uphill and downhill yarding was almost the same in actual operations, it appears that workers can't choose only uphill yarding at their work sites, since they are restricted by working conditions such as forest road density, arrangement and so on.

Near-Accident Analysis in Mobile Tower-Yarder Operations

General Analysis

Figure 1 shows the relative frequencies of the place, time and type of work at which near-accidents occurred.

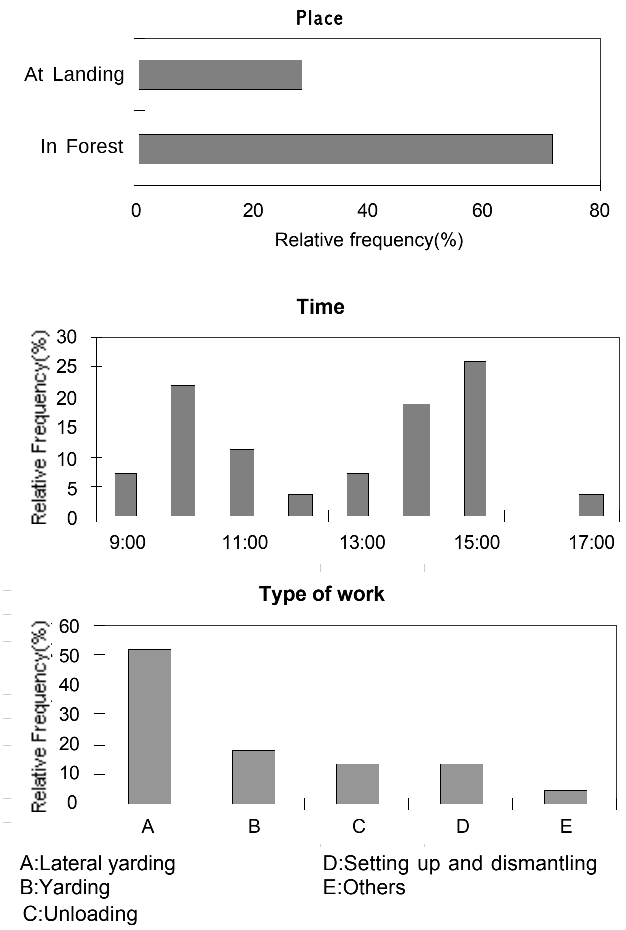

FIGURE 1. **Relative frequencies of near-accidents by place, time, and type of work.**

Most near-accidents occur in the forest, especially at 10 o'clock in the morning and from 2 o'clock to 3 o'clock in the afternoon. This fact corresponds with previous reports (Iwakawa, 1993; Okuda, 1989), which analyzed actual forestry worker accidents. Of these accidents, 52% occurred during lateral yarding, 17% during yarding, 13% during unloading and 13% during set up and dismantling. This information indicates that lateral yarding is very dangerous.

The most frequently occurring near-accidents were as follows:

- Logs or wire rope hitting a worker during lateral yarding, when the logs being skidded came off an obstacle such as a stump, felled tree or stone after the skidding line was pulled strongly.
- Swinging logs hitting a worker during yarding operations.
- Logs falling from above and hitting a chaser at a landing during unhooking operations.
- A carriage or wire rope falling from above and hitting a worker because of breaking of wire rope.
- A mobile tower-yarder collapsing due to careless set up.

Factor Analysis

In order to find the factors related to the near-accidents, the author conducted quantification theory (II) analysis (Hayashi, 1974). This theory is a kind of multivariate analysis, which can extract effective information from the qualitative data. The author considered such factors as the kind of business, age, type of work, forestry work experience, the cable yarding method, the span length and the yarding direction. The factors which show the largest numerical values for partial correlation coefficient and range of categories were forestry, work experience, age and the cable yarding method (Table 2). Therefore it is thought that these factors are most concerned with near-accidents. The categories showing negative values in Table 2 are where near-accidents occur often. Therefore, we can see that it is easy to experience near-accidents as years in forestry work increase. Presumably, highly experienced forestry workers have also been engaged in the yarding operations with the mobile tower-yarder longer. In the age category, many workers in their twenties and forties experienced near-accidents, accounting for 72% and 75% of all such workers, respectively. Apparently the young workers (their twenties) experienced near-accidents easily because of their lack of technical experience. Since the forestry workers in their 40’s had abundant experience, this might increase their chances of having a near-accident. On the other hand, 50-year-old forestry workers’ experience with near-accidents was less than that of the workers in their forties. One reason for this may have been that the workers in their fifties had less forestry work experience than those in their forties.

The near-accidents occurred more in the non-skyline method than in the skyline method. As mentioned above, a lot of near-accidents occurred during the lateral yarding operations. Therefore we can assume that near-accidents

Items	Categories	Numbers of samples	Category scores	Ranges	Partial correlation coefficients
Type of forestry related businesses	Forest owner's assossiation	41	-0.195	0.502	0.203
	other	26	0.307		
Age level (years)	< 29	22	-0.601	1.547	0.413
	30-40	13	0.276		
	40-50	20	-0.085		
	>50	12	0.945		
Position	Operator	23	0.287	0.646	0.208
	Choker setter	15	-0.032		
	Operator & Unhooker	16	-0.358		
	other	13	-0.031		
Work experience in forestry (years)	>5	29	0.659	1.451	0.452
	5-10	12	-0.225		
	10-20	15	-0.514		
	>20	11	-0.792		
Cable yarding method	Non-skyline	50	-0.360	1.418	0.403
	Skyline	17	1.058		
Cable span length (m)	>100	24	-0.160	0.404	0.094
	100-200	35	0.054		
	>200	8	0.244		
Frequency of yarding direction	uphill > downhill	20	0.099	0.423	0.164
	downhill > uphill	24	0.165		
	uphill = downhill	23	-0.258		

TABLE 2. **Influence of factors on near-accidents based on quantification theory (II).**

occur often in the lateral yarding operations with the non-standing skyline method.

Safety Evaluation of Mobile Tower-Yarding Operations

In order to evaluate the safety of operations with the mobile tower-yarder, the author had the respondents evaluate the six items of safety operation shown in Figure 2 by one of five levels. The respondents rated each item better than average except "the safety in lateral yarding operations". Comparing the non-standing skyline method with the standing skyline method, the evaluations of "teamwork between an operator and a choker setter" and "safety of the returning of carriage to the stump site" were a little higher in the former, but little difference was apparent between the values of other items.

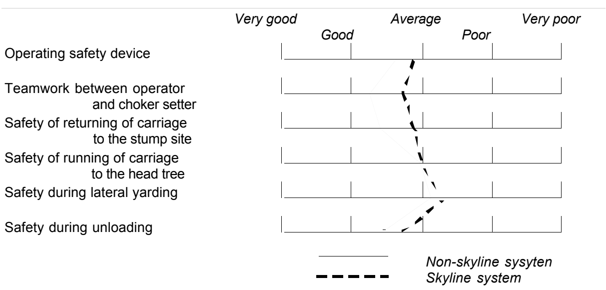

FIGURE 2. **Safety level for six activities.**

The author conducted quantification theory (I) analysis, in order to find the factors related to safety evaluation. The author took the mean of the value of each item as the outside criterion (criterion variable). The factors which were considered were as follows: type of work, forestry work experience, cable yarding method, span length, yarding direction and the kind of tower-yarder. Table 3 shows the results of the analysis. The factors, which show the largest values for the partial correlation coefficient and range of categories are kind of tower-yarder, cable yarding method and the forestry, work experience. Models A, B, C and D equip the main body with the drum for the skyline. The evaluation of Models A and B was good, but that of D was bad. As for the evaluation of safety, a difference was seen between machines with similar functions. The non-stand-

Items	Categories	Numbers of samples	Category scores	Ranges	Partial correlation coefficients
Position	Operator	24	-0.058	0.229	0.264
	Choker setter	14	0.143		
	Operator & Unhooker	16	-0.086		
	other	14	0.054		
Work experience in forestry (years)	< 5	31	-0.137	0.358	0.370
	5-10	13	0.007		
	10-20	14	0.220		
	> 20	10	0.109		
Cable yarding method	Non-skyline	51	0.154	0.617	0.552
	Skyline	17	-0.463		
Cable span length (meters)	< 100	27	0.012	0.040	0.044
	100 - 200	33	-0.015		
	> 200	8	0.025		
Yarding direction frequency	uphill > downhill	19	0.003	0.071	0.080
	downhill > uphill	25	0.033		
	uphill = downhill	24	-0.037		
Tower-yarder model	A	6	0.728	1.424	0.620
	B	3	0.467		
	C	5	0.031		
	D	9	-0.696		
	E	43	0.004		
	F	2	0.080		

TABLE 3. **Influence of factors on near-accidents based on quantification theory (I).**

ing skyline method was safer than the skyline method. While the workers with little forestry experience considered the safety of the operations with mobile tower-yarder to be low, the highly experienced workers considered it to be high.

CONCLUSIONS

The results of this study were as follows:

- Most cable span at the yarding sites was 150m or less in length.
- 60% of the respondents had experienced near-accidents during the operations with mobile tower-yarders. Many workers considered downhill yarding to be more dangerous than uphill yarding. Apparently the workers can't choose the yarding direction at an actual yarding site due to restricted working conditions.
- A lot of near-accidents occurred in such activities as lateral yarding and choker setting.
- The factors such as forestry work experience, age and the cable yarding method influenced the occurrence of near-accidents. Near-accidents occurred more often in the non-standing skyline method than in the skyline method.
- The safety evaluation of the lateral yarding operations was low. The kind of tower-yarder, the cable yarding method and forestry experience was important factors affecting the safety evaluation.

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Logger's Loads at Work with Power-Saws

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Abstract

The introduction of powersaws into forestry work in the mountain regions of Europe brought decrease in physical workload, but the difference was not as big as expected. One of the reasons is that loggers are paid per piece. The energy consumption dropped, but heart rate remained high, due to new static loads. On steep terrain the workloads measured with the heart rate exceeded the limits for heavy physical work in more than one-half of the cases. When the workers have smaller physical capacity (size, nutrition, training), the work becomes even more difficult or the effects are smaller.

Powersaws cause new serious injuries at work. Powersaws have been improved many times in the past 50 years, but even the best ones, which satisfy all standardised allowed limits, still cause loss of hearing, vibration disease and intoxication with exhaust gases. The work, which is typical for the Alps, is delimbing with the powersaw in the forest and debarking in the mill. The daily noise-load is about 98 dB(A) and the vibration load of loggers ranges from 6 to 12 ms^{-2}. After some years of work these loads must cause serious health injuries. The exhaust gases that cause concentrations of toxic matter in the air are above the maximum allowed limits.

When introducing powersaws in new regions we must decrease these harmful influences. Only the best powersaws should be used and all known preventive measures must be taken.

KEYWORDS--*Logger, workload, chainsaw, noise, vibration, exhaust gases*

WORK LOAD OF LOGGERS

Harvesting of trees has always been difficult work. In the times where manual work predominated Lehmann (1953) stated, that the logging profession is energetically very demanding, since the daily energy consumption is as high as 4300 kcal. Only manual work at mining, railway building and corn field harvesting was more difficult. Hettinger (1980) estimated the profession of forest workers to be energetically the most demanding one, because the work energy consumption varied between 1500 and 2500 kcal with an average value of 2000 kcal. This is on the upper limit of permanent endurance and it is the highest energy consumption of all professions. Some mining jobs may be even more difficult, but the average energy consumption of the profession is smaller. According to his statements the energy consumption at different felling work operations are 4,3 - 13,0 kcal (18-55 kJ). A comparison between hand work and the first chainsaws shows a smaller consumption on chainsaw work (Hettinger handwork 5,7 - 6,2 kcal, chainsaw 4,1 - 4,9 kcal). Also the results of numerous other studies (Table 1) show that the energy consumption during work with a chainsaw is significantly smaller than during hand work. This means, that the amount of dynamic physical work is smaller. However, this is not in turn reflected in a less difficult work, since the static physical work load becomes higher, especially when using the earliest heavy chainsaws.

From Table 2, the heart-beat rate, which is the correct measure of work load when static physical, physical and stress loads are included, does not decrease significantly with the introduction of the modern chainsaw working methods. The displacement of physically demanding hand debarking to the mechanised central work places has possibly decreased the difficulty of a logger's work. At the same time the work effects increased considerably. Since the workers are paid per piece, their ambitions for wages increase and they work faster with the chainsaw. In addition, the speed of action of motor parts urges them to a higher tempo. Therefore, their work loads have not dropped significantly. This is shown by the high cumulative relative frequency curves on Figure 1 (Lipoglavsek 1992).

The work heart rate, i.e. the difference of the heart beat rate at rest, surpasses the endurance work load limit (35 beats above the initial pulse) in more than one-half of working sites in Slovenia and by different work technologies. Felling and producing full length wood of broadleaved trees is the most difficult work. This is followed by the assortment methods with hand barking and firewood production and preparation of assortments in the bark. Felling and preparation of multiple length assortments of conifers together with the work in a group with the tractor driver is not as demanding. However, all these felling methods are very hard work. The heart rate and work load vary considerably among different fellers and working sites, during a certain working day and also between different working operations. The most demanding opera-

Author (year)	HAND WORK	Energy consumption kcal/min	CHAIN SAW WORK	Energy consumption kcal/min
HETTINGER (1980)	Removal of swelling and felling notch making	6,9 - 13,0		
	Limbing by axe	4,5 - 9,6		
	Barking	4,3 - 5,6		
	Splitting	6,0 - 6,4		
	Felling by saw	5,7 - 6,2	Felling	4,1 - 4,9
TOMANIC (1974)	Different work operations at felling	3,3 - 6,6		
	Limbing by axe	6,0	Limbing	5,5
DURNIN (1967)	Cross-cutting	7,2 - 8,6	Cross-cutting	4,3
			Felling	5,4
RONAY (1975)	Felling by axe	3,0 - 3,1	Felling	2,1 - 5,0
	Limbing by axe	3,5 - 5,0	Limbing	2,2 - 4,8
			Cross-cutting	3,3 - 4,1
RONAY (1989)			Sawing	3,9 - 4,5

TABLE 2. **Energy consumption at felling.**

Author Country	**Felling methods (technology)**	**Heart-rate: average on work** Absolute (b/min)	Difference to rest (b/min)
DYERR et a.	Felling of conifers by hand tools		
Austria 1958	on steep terrain	104 - 159	65
	on flat terrain	94 - 193	33
WENCL, WENTER Austria 1971	Felling of conifers by chain -saw		
	clear-cut	124	28
	thinning	117	28
VAN LOON The Nederlands 1971	Felling by hand-saw and axe	121	
	Felling by chain-saw and axe	135	
	Felling by chain-saw, limbing by axe, hand-barking	120	
RONAY Tchechoslovakia 1989	Felling by chain-saw	100 - 138	24 - 60
VIK, Norway 1969	Felling of conifer -full length	130	
BOMBOSCH Germany 1988	Felling of conifers and broadleafs	93 - 150	31 - 91
UDE, Slovenia 1971 (n = 1)	Limbing by axe	113	46
	Limbing by chain-saw	94	27
SUSNIK, Slovenia 1971	Felling of conifers by chain-saw and hand-barking (assortments)	134	49
	Felling of broadleafs by chain-saw	127	42
LIPOGLAVSEK, Slovenia 1992	Felling of conifers and broadleafs - long wood	109	39

TABLE 3. **Heart-rate of logger.**

tions are releasing, wedging and hand barking the tree, splitting firewood and putting branches together (work pulse 50-70 beats/min). The average daily work heart rate reached as high as 74 beats/min (long beech wood in a steep terrain) and momentarily absolute heart rates up to 210 beats/min were measured.

Even higher rates were measured when pulling the rope of a tractor-winch and when mounting cable-cranes, but these loads do not last long and therefore, the work at skidding wood is never as demanding as tree felling (Figure 1). The work of loggers is the most difficult work in forestry and it should be better paid.

The physical work capacity of loggers was average or slightly below the average of working population in Europe in most cited investigations. The physical work loads are still mainly with a chainsaw and therefore the physical work capacity is important. Undoubtedly, the work load depends on the work capacity (for example: work heart rate in the productive time = 39,9 + 4,296 LPI (Leistungspulsindex)).

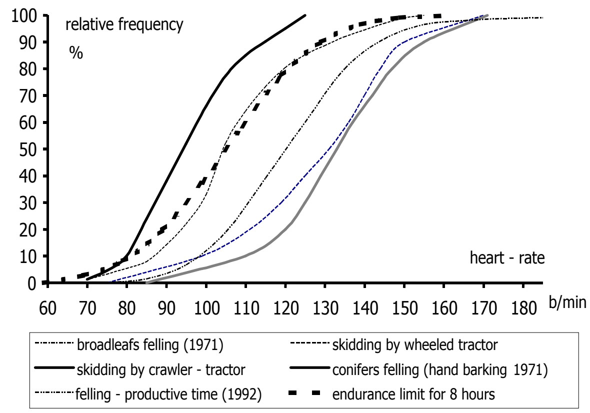

FIGURE 1. **Noise-loads of lumbermen - daily time distribution**

If the workers have a smaller work capacity because of their physical constitution, lower nutrition or similar, their work load is higher and more often surpasses the allowed endurance limits.

WORK ACCIDENTS

Harvesting trees should be better paid also because it is dangerous. There are a lot of accidents since the work is done by many people. For instance, in Slovenia the number of accidents is higher at felling and the preparation of assortments than at other forest operations and it was increasing until 1993, which is the last year with available data (table 3).

Although the chainsaw is seldom the source of injuries, it still dominates among all means of work (9-10% of accidents). Operations working with a chainsaw running quickly, which can cause more severe accidents. The consequences of chainsaw cuts (face, legs) are more serious than the injuries with the hand tools. We began to protect the fellers against some injuries caused by the chainsaw only later, when the technical development and the development of working techniques progressed. Due to kickback during delimbing, the chain stop was developed. Because of leg injuries, the wearing of underlayed trousers became mandatory.

NOISE - LOAD

Noise load of loggers depends on the noise level of the chainsaw in use, working technology and working conditions. The correlation between noise level of a chainsaw and the noise load of loggers is linear:

(noise load in productive time = 31.53 + 0.6585, noise level at full load in test procedure), but it is variable due to many other influences. The daily noise-load at work with older, used chainsaws is on the average 0,7 dB(A) higher than the noise load at work with new chainsaws of the same type.

The noise loads are higher for modern working technologies of long wood production with a small hand-work part as well as small trees and full-length felling methods (Table 4). Even felling with chainsaws, which satisfy the noise level requests by international standards (EN 608 - 1994, ISO 11681-1-1996; 103 or 105 dB(A) on tests by full-load - ISO 7182-1991) causes a much higher daily noise load of loggers than the allowed values, where the hearing is not yet damaged (85 dB(A) - Figure 2).

Figure 2 also shows that the noise loads of loggers is significantly larger in modern technologies of long wood production than in the technologies of short-wood (assortments) with more hand work.

VIBRATION - LOAD

The studies of vibration loads of loggers are rare, although there exists plenty of data on the vibrations of chainsaws. The standards of allowed limits for vibration load during working time does not exist, although the allowed vibration level on the handles of a chainsaw is known: 12.5 and 15 ms^{-2} WAS in ISO 11681-1-1996. The modern professional chainsaws do not surpass those limits in the testing procedure during crosscutting.

But in Slovenia we measured when felling long-wood, the vibration loads during productive working time were between 6.2 and 12.3 ms^{-2} WAS (vector magnitude) or during total working time (8 hours with 3 hours of unproductive time) between 4.9 and 9.7 ms^{-2}. After some not completely correct conclusions from the ISO 5349 standard, we can put the allowed load limit at 6.8 ms-2 WAS (= V 3*3.919). Above this limit the logger is overloaded with vibrations and we can expect that 10% of them will get vibration disease after 7.7 years and 50% after 17 years of work with the chainsaw. When the daily effective working time with a chainsaw lasts less than 2 hours (such

Work - operation	**1975-83**	**1984-88**	**1989-93**	**1993**
		% per number		
Felling	12.0	9.6	11.1	11.0
Preparation of assortments	23.0	22.3	24.7	35.6
sawing	19.0	14.0	11.4	16.1
limbing	6.2	9.2	12.8	17.8
Hand - skidding	6.6	4.8	5.1	3.4
Mechanical skidding	9.7	31.1	25.9	22.9
Total number of accidents	7587	3681	1922	236

TABLE 4. **Accidents at work in state forests of Slovenia (350.000 ha, 900.000 m^3 netto, 1993)**

COUNTRY/YEAR AUTHOR	WORK - TECHNOLOGY	CHAIN-SAW NOISE AT CROSSCUTTING dB(A)	AVERAGE NOISE - LOAD OF LUMBERMAN L_{EKV}-dB(A)
GERMANY 1974 (Lipoglavsek)	Spruce mature forest, assortments, hand-barking (Stihl 045)	102	93
	Beech mature forest, firewood preparation (Stihl 045)	102	96
	Spruce mature forest, full length, no barking (Stihl 045)	102	96
	Spruce polewood forest, assortments 4-7 m, no barking (Stihl 031)	104	97
	Beech polewood forest, full - length (Stihl 031)	104	98
GERMANY 1988 (Bombosch)	Pine polewood forest, crane-length assortments, previous hand skidding (Stihl 034)	104	96 - 102
	Beech polewood forest, full length (Stihl 028)		102
SLOVENIA 1994 (Lipoglavsek)	Average of different circumstances		98
	Spruce mature forest, no barking, assortments and long-wood, putting branches together (Husqvarna 254)	102	94
	Fir mature forest, no barking long wood and multiple lengths without puttingbranches together (Husqvarna 266)	102	102

TABLE 5. Motor-saw's noise and noise-load of logger.

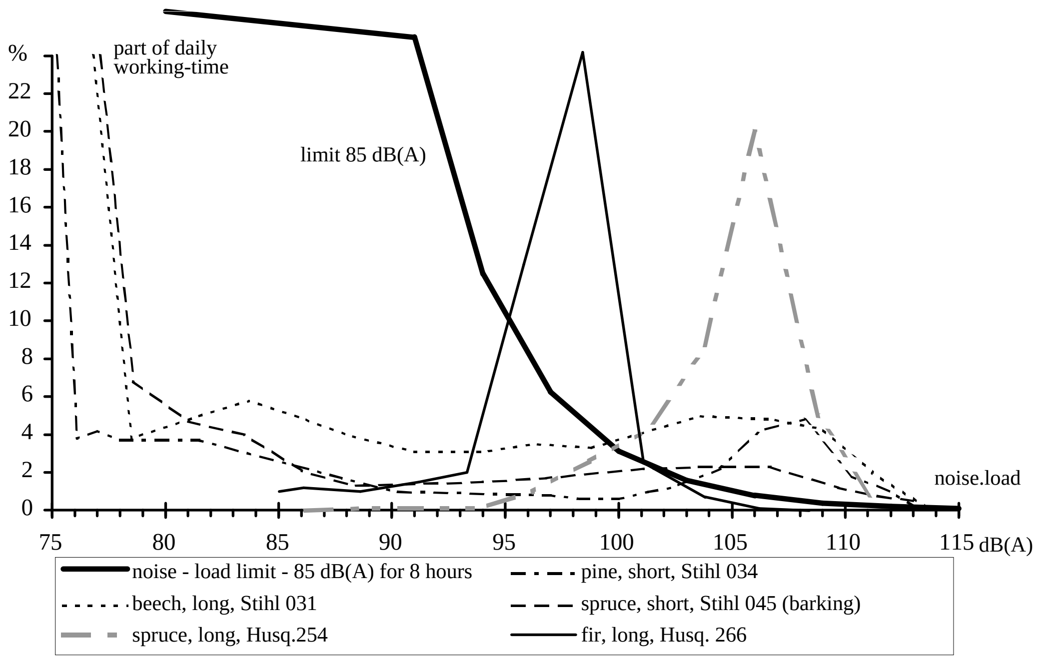

FIGURE 2. Noise-loads of lumbermen - daily time distribution

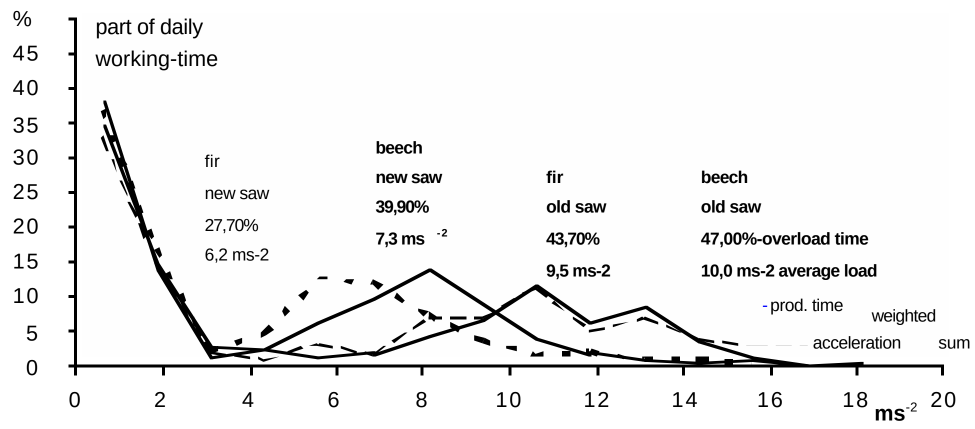

FIGURE 3. Vibration - load of lumbermen - daily time distribution - comparison: beech to fir, new to old chain saw

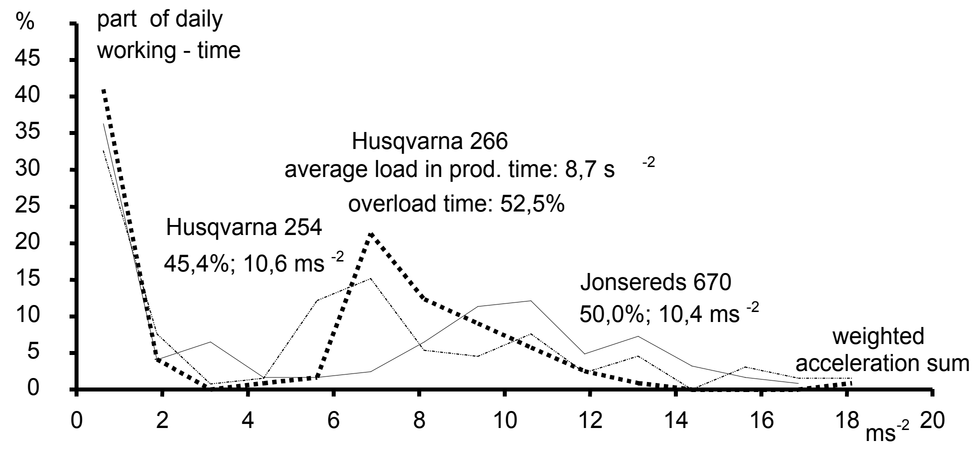

FIGURE 4. Vibration-load of lumbermen - daily time distribution - different chain-saws

technology is usual somewhere in the Alps) the above mentioned limit can be multiplied by a factor of 2. The vibration loads of loggers measured in Slovenia during productive time are below this second limit. These investigations again revealed, that the older, used chainsaws cause greater loads. The vibrations on the rear handle are larger than on the front handle. The vibration loads are higher at felling of broad-leaved trees than at felling of conifers (Figure 3) The vibration loads are different at work with different chainsaws, but the differences are small although the time distributions are very different (Figure 4). The vibrations in the vertical direction, i.e. in the direction of piston displacement, contribute the greatest part of the vibration load. The same is true for delimbing, because it lasts the longest time among the different operations of chainsaw work in a working day.

We can conclude, that the vibration loads are present in a logger's work. However, we do not know what consequences they cause. Even if they possibly do not menace the health of forest workers, they certainly diminish their working capacity. Therefore, all preventive measures have to be taken in order to decrease the vibration load. Ergonomically the best, light chainsaws (vibration on test under 12.5 ms^{-2} WAS) with warmed handles should be chosen, antivibration devices should be regularly maintained, gloves worn, the chain sharpened correctly, a warm meal during the work should be assured and alcoholic drinks avoided.

EXHAUST GASES

Investigations of the concentration of toxic matter in a feller's working environment including all the carbon monoxides (CO) from exhaust gases, found they do not menace the health, because their concentration in the air diminishes in open air where the air moves quickly. An exception in special circumstances (terrain holes, snow holes, young stands) showed higher concentrations in larger time intervals. The chainsaw emits a lot of CO (twice the amount of a car) and carbo-hydrogens CH (half the amount of a car) relative to its power. The amount of emission depends very much on the carburator adjustment and in turn on the mixture of fuel and air. Intoxication can happen earlier because of the physically difficult work and therefore greater pulmonary ventilation. Exposure to augmented concentrations of CO can cause a greater frequency of heart and vascular diseases or even greater difficulties. Loggers have more renal cancer, more blood and lymphatic system cancer, which can be caused by some CH in the exhaust gases (benzene, benzopyren). The measurements of CH concentrations at felling large trees, where the situation is worse, showed concentrations much below the MAK (maximal allowed limits). But it is questionable if the limits are well determined, since it was proven that the carbo-hydrogens may cause cancer.

On the contrary, the new investigations show that the measured momentary concentrations of CO in front of the respiratory organs often, sometimes even in more than one-half of measured cases, surpass significantly the MAK values. The momentary concentrations and not the average values in long time intervals are important by those matters, which cause the acute intoxication (also CO). Saturation of hemoglobin in the blood with CO was in too large (more than 5%) in felling in old stands. It was highest in the second and third hour of work and slowly dropping afterwards, due to lower working tempo. Many improvements of chainsaws are possible (adjustment of carburator, special fuel, catalysator, fuel injection), but nobody is really interested in using and paying for the benefits.

CONCLUSIONS

Different logger loads at chainsaw work and numerous injuries caused by chainsaws show that this machine is not suitable for men. In the near future we will not be able to work in the forest without chainsaws but we should avoid using chainsaws whenever we can harvest wood with machines: fellers, harvesters, processors. If at least one chainsaw working operation (felling, delimbing, crosscutting) is mechanised, a part of a logger overload is avoided. When chainsaws are used, they have to be used with all known measures against the dangers of injury and health damage.

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Stress And Strain Effects Of Forest Work In Steep Terrain

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ABSTRACT

A reduction of the heavy physical workload in forestry has been achieved on passable terrain primarily through the mechanisation of operations. The possibility for similar reductions on steep terrain is limited, which is why other working condition improvements must be considered.

The goal of this study is to determine the stresses and strains of forestry workers in steep terrain. The resulting effects of varied work structuring and technical improvements are to be investigated on the working conditions.

Using a multi-dimensional measuring concept - combining different stress and strain parameters – the effects were analysed and statistically evaluated. Possible health consequences were determined using a written questionnaire.

The investigation results in three main findings: (1) reduced carbon monoxide exposure when using alkylat fuels, relative to conventional fuel, during chainsaw work; (2) a clear reduction in the work load for the chokersetter when job-rotating with the yarder operator; and (3) a significant work demand reduction when using a mechanised slack-pulling carriage.

KEYWORDS--*Forestry, steep terrain, stress, strain, alkylat fuel, job-rotation, mechanical slackpulling*.

INTRODUCTION

A reduction of heavy physical workload in forestry has been achieved on passable terrain primarily through the mechanisation of operations. The Austrian forest inventory shows that only 40% of the forest terrain is suitable for mechanisation when taking into consideration the current technical feasibility, such as the harvester – forwarder combination. Additionally, this machine combination is further limited by local ground conditions such as larger rocks or sensitive soils, as well as the small forest ownership structure of Austria. The working procedures in steep and difficult terrain must continually be ergonomically evaluated and improved. There must also be an increase in the consideration of the personal development potential associated with the work activities carried out by the forest workers.

A large number of studies have been carried out that investigate noise and vibration. In this area there has been considerable advancements through technological improvements. The problem of exhaust gases is however still a controversial theme. Although many assume that while the work is carried out outside, the gases are continually being transported away and therefore does not presents a problem. More evidence now exists that indicates that carbon-monoxide and aromatic hydrocarbon compounds can occur in dangerous concentrations (Knorzer and Schulz, 1997; Bunger et al., 1995). These results are however mainly instantaneous measurements or extrapolated calculations from shorter observations.

As an indicator for the difficulty of the work the heart rate is measured to determine the work load. In the field of forestry, Kaminsky (1953) carried out the first research regarding work load associated with timber extraction with sled mounted winches in mountainous areas. For mid-European mountainous conditions recent research work includes that of Stampfer (1996), Boltz (1988), Bombosch (1988), Schmid-Vielgut (1985) and Wencl (1982). Kirk and Parker (1994) present an overview of work loads of varied forestry jobs on steeper slopes in New Zealand. Job-rotation is used extensively in fully mechanised operations in Scandinavian countries, Apud and Valdes (1995) reports on possible use in conventional common forest work.

The goal of this study is to determine the stresses and strains of forestry workers in steep terrain. The resulting effects of varied work structuring and technical improvements are to be investigated on the working conditions.

The paper presents the methodology that was used in the study, presents an overview on the work demands from various timber extraction operations in mountainous conditions and discusses the effect of different technical and organisational improvement measures.

METHODOLOGY

Work Systems

Timber extraction in mountainous conditions cannot attain the highest level of mechanisation. The possible work systems are cut-to-length, stem and tree extraction. In these cases the felling is always completed with chainsaw and the extraction usually with a cable yarder. Hand delivery of the timber using a pickeroon is seldom. The log-making occurs on the road-side either motor-manually or with a processor.

Job-rotation between the yarder operator and the chokersetter was researched in stem extraction. The jobs were changed during the midday break. The “team” comprised of two people, a yarder operator and a chockersetter that work with two sets of slings, each with three chokers. The average production was 5.7 m^3 per work only time with an average piece diameter of 34 cm. The maximum extraction distance was 200 m and the average lateral pull was 13.8 m (maximum = 30 m). On average 2.6 pieces were extracted per cycle.

Additionally, during the extraction of cut-to-length timber a variation of with and without mechanised slack pulling was tried out. A productivity of 17.5 m^3 per work time only was achieved. The maximum extraction distance was slightly higher in the variation with mechanised lateral hauling (155 m as opposed to 130 m). The lateral hauling distance (between 9 and 10 m) and the average number of pieces per cycle (4.5) were similar. The ground slope in both areas was 60 to 80%.

Measuring exhaust fumes

A comparison was made of the carbon-monoxide exhaust from the chainsaw work using standard fuels and special fuels (Alkylat). The known harmful substances benzol, aromatic, olefins, n-hexane and lead are present in high concentration in normal petrol. In the special alkylat fuels they are almost non-existent. The results are a positive influence on the health of the worker, and especially a reduction in cancer risk.

Carbon-monoxide is a poison for the body as it forms carboxyheamoglobin (CO-Hb). This causes the oxygen transport through the blood to be paralysed. Already with the low concentration of 15% headaches, vision and hearing disturbances, dizziness and heart flutters can occur. Higher concentrations in combination with physical work can cause sudden unconsciousness and repeated poisoning can lead to damage of the central nervous system.

The maximum work place concentration (MAK-value) for CO is 30 ppm. The MAK-value is the highest allowable work place concentration with an exposure rate of 8 hours per day and 40 hours per week that does not lead to long term health damage.

The level for harmful substances is measured by the concentration at the work place or in the body. Exceeding established thresholds requires additional measures to be taken to protect health. To continuously stay under the threshold value means that during control measurements the value must be lower than 1/4 of the MAK value.

There is also a limit with regard to the exposure time for substances that have short term fluctuations. For carbon monoxide a thirty minute average is not allowed to be higher than double the MAK value four times during the day (KZW...Short term value).

During felling work (stem extraction), a number of carbon monoxide measurements were carried out using a wearable gas concentration measuring device. The equipement (PM-7700) is very suitable for use in the field due to its size and weight. The required monitor was positioned in the vicinity of the workers mouth using a clip.

To determine the carbon-monoxide variation between the various fuels, the changing weather conditions, temperature, air humidity and wind velocity were recorded. On the days that the measurements were made the weather conditions were very similar, hence near identical investigation conditions can be assumed. Even though these conditions existed, the harmful substance concentration relative to the work and surrounding conditions varied considerably.

Heart-rate measurements

Electro-physiological measuring methods are used almost exclusively these days for the interference free recording of the bio-electrical signal of the heart muscle potential (EKG-Impulse). The so called R-spike is used as an easily recognisable feature since it is usually the highest spike in the EKG. From the distance between two R-spikes the actual beat to beat heart rate can be calculated (Schandry, 1988).

In this study the EKG was measured using a simplified bipolar breast-wall circuit using three one-way surface electrodes. The attachment locations are interesting in that they should be chosen so as to minimise artifacts (especially movement and muscle-potential artifacts). The recorded bio-signals are, after amplification and digitisation, recorded on a data storage devise (Physio-Logger) which is attached to the subject. Simultaneously a work study is carried out on a Data-Logger to allow stresses and strains to be associated with specific work tasks. The heart-rate and work study data are combined with a specific computer program.

Each work task was investigated using three workers on three different days. To ensure that the forestry workers used in the study could be compared, each had their individual maximum work load determined through the use of physical output tests and cycle ergometer.

The endurance limit, which is defined as the work rate that can be maintained for 8 hours without extra work breaks and without a reduction in work rate, is used as a criteria for the maximum work load. Should this parameter be determined using the heartrate, then it is a work pulse of 35 beats/min (heartrate – rest pulse), whereby the rest pulse is measured when the subject is sitting. In this case the characteristic rest pulse was taken to be the minimum pulse of the day.

In total the endurance limit should be viewed quite critically, since an average value for a single person and their possible work load is the critical value. This problem can be rectified when the individual endurance limit, for example the maximum heartrate reserve is determined. Using this method, the work pulse is taken to be a percentage of the maximum achieved on the cycle ergonometer. The endurance level is approximately 40% of the heart rate reserve (=%CVL ...cardiovascular load).

RESULTS AND DISCUSSION

Work demands and work demand consequences on steep slopes

Figure 1 shows that forestry workers in steep terrain work at or over the endurance limit (Stampfer et al., 1997; Stampfer, 1996). The exceptions are the activities of the cable yarder machine operators and processor operators whose work can be categorised as easy physical work. The felling with chainsaw, the hand delivery of wood and the breaking-out by cable extraction is heavy work. These results indicate the need for organisational improvements.

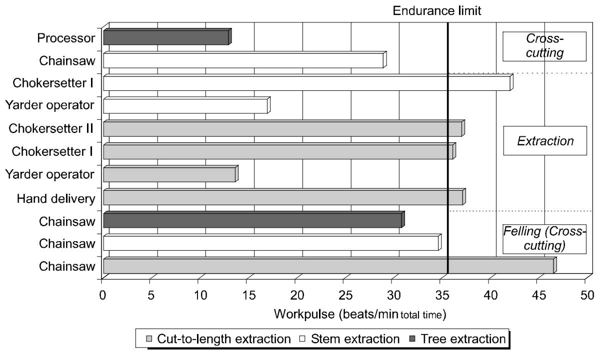

FIGURE 1. Comparison of work demand for varied work tasks on steep terrain

Analyses showed that the high excedence of the endurance limit by felling in cut-to-length extraction is caused by too few rest breaks. Although a great number of short rest breaks were taken, the length of these rest breaks were too short to provide adequate recovery. The reason for the lack of rest breaks is most probably the production pressure from the company and the possibility of increasing the earnings. Stampfer (1996) provides an example of rest break organisation for similar earning potential.

The hand delivery of timber is only recommended in exceptional cases (in the vicinity of the road and by timber that is spread out caused by a calamity). However, also improvements are necessary for the break out by the cable extraction. Fundamentally, two chokersetters provide a work demand reduction, whereby extensive measures must be taken. The possibilities shown later for cable extraction with mechanised slack pulling and job rotation between the operator and the chokersetter is a step towards more humanised forestry work.

A written questionnaire of 137 forest workers who left their work prematurely (Griesser 1996), in the time frame of January 1991 to march 1996 showed the average age to be 54,2 at the time of finishing work. One worker was 37 years old, while four workers left at the age of 60.

At the time of leaving, the reason given was most commonly a injury to the back or joints, especially for the early invalids. This is not surprising when one realises that by motor-manual activities 40 to 50% of the work is carried out with a bent back and single sided strain of the muscles and tendons. The high percentage of workers with rheumatic sicknesses can be explained by the continuous changing weather conditions (for example heat, rain, snow etc.) at the work place. Genetical disposition and unhealthy diets, normally combined with overweight, can lead to increased probability of sickness. The rate of deafness, 40%, is still the main form of injury.

Exhaust gas problems with chainsaw work

Figure 2 shows the CO-concentration in the air by the use

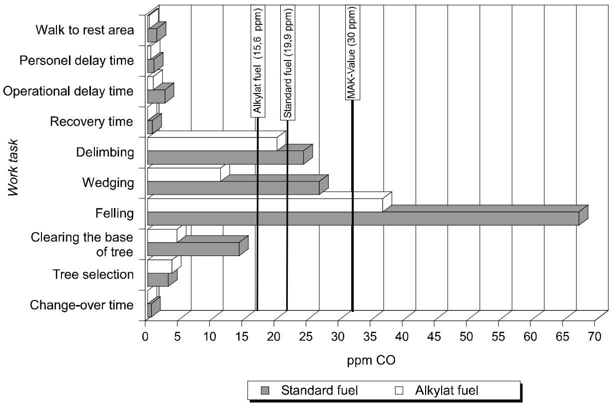

FIGURE 2. Carbon-monoxide exhaust gas during felling (stem extraction)

of conventional and alkylat fuels. The average value for many shifts resulted in 19.9 and 15.6 ppm CO respectively, whereby the MAK value of 30 ppm was not exceeded. During the time of the investigation the KZW value was also not exceeded. However, the threshold value (7.5 ppm) as an indicator for the need to take organisational measures was reached.

The few recent studies on CO-exposure for forestry workers indicated much higher values. Nilson (1987; after Bunger et al., 1995) had calculated average values of 31.0 ppm for conventional fuels, while Bunger et al. (1995) values of 25.8 ppm with the use of alkylat fuel. The only recording of the emissions over a whole shift gave an average of 24.3 ppm. Two reasons can be given for the low carbon-monoxide loads: (1) the recording of complete shifts including necessary rest breaks and (2) a correct carburettor setting.

As also confirmed by Bunger et al. (1995), the felling task is the one where the greatest gas concentrations occur. One explanation for this is the extreme back position whereby the chainsaw is very close to the breathing zone of the forest worker and therefor higher CO values were registered. The maximum values attained by the conventional fuel variation was 610 ppm. In general the concentrations are high and a problem when delimbing dense tree crowns, forest work in dense understory and working where there is minimal wind velocity.

The reduction of CO load brought about by the use of alkylat fuel was 27.5%. These results reflect values obtained during monitoring, which were 20% (Schierling,

1993) and 25% (Schwanitz et al., 1995), but are clearly below those values from Weiger and Barth (1992) who reported a 51% reduction.

To present the differences in the harmful substances, an average value comparison was made using a t-test. Since the data wasn't normally distributed a natural log transformation was made from the values. The CO-load for the chainsaw work with alkylat fuels was for the work activities clear stem (p=0.019) and felling (p=0.002) significantly lower compared to using the standard fuel. For the other work activities no significant difference could be established. The individual values can deviate significantly, however as already mentioned, the surrounding influences can be important factor but are difficult to calculate.

Job-rotation for cable yarding

Job rotation as an organisational measure for reducing the work load has been known for a long time. The practical implementation in mid-European forestry however is almost non-existent. The activity change between the operator and the chokersetter by cable extraction provides an excellent opportunity. In this study the workers changed each half a day, whereby changing on a daily basis is also possible and perhaps more practical.

Figure 3 shows the work loads to be similar. For the complete work time there are no excedances of the endurance limit if this is presented as a percentage of the maximum heart frequency reserve. In comparison the values for the chokersetter alone is above the allowable. In Figure 3 it is also clearly visible how the individual endurance limit varies.

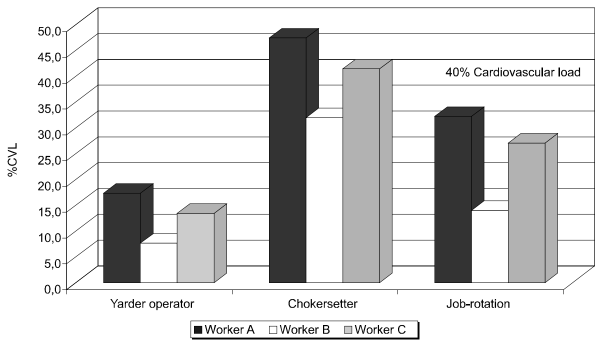

FIGURE 3. Work demand reduction through job-rotation between operator and chokersetter

In comparison to the normal operator activity there is an 80% increase in the work load, but a 72% reduction is achieved for the heart-rate of the chokersetter. From the point of view of a simple machine activity and a physically demanding activity for the chokersetter, the achieved effect is desirable.

To improve the personal development of the forest worker, their training, organisational and decision making influences should be extended. As an effective measure to increasing the activity sphere for job-enrichment is the implementation of partially autonomous groups. The work content is changed so that the individual workers or work groups have larger responsibilities and that higher qualification qualities can be expected. Planning (marking and organisational) and monitoring (measuring and success control) parts of the work could be carried out by the forest worker.

Cable systems and mechanical slackpulling

Heart-rate was monitored to identify possible work demand differences for the chokersetter using systems with or without mechanised slack pulling. In Table 1 it is possible to notice that without mechanical slack-pulling the work load for the total work time is above the endurance limit, while with the aid of mechanical slack pulling it is slightly below. Even when including the mid-day break into the work time the cable work does not drop below the threshold value. The work activities pulling out the rope, helping break-out and any form of movement on the steep slope causes the highest work demands regardless of the cable system.

To make a statistical comparison of the differences between the two variations the averages were compared using a t-test for independent samples. The requirement for normality was met for these combined data sets. The work demand for the chokersetter I by the cable extraction with mechanised slack-pulling is significantly lower ($p<0.1\%$) as that without. There were clear differences shown especially in the work only times.

The results confirm the notion that from an ergonomical point of view, only systems with mechanised slack-pulling should be used. However also other measures to improve the work demands situation should be used.

CONCLUSIONS

The goal of this paper is to present the work system specific work demand and loads, and the work demand consequences of forest work in steep and difficult terrain. The ergonomic consequences of measures for the organisational and technical improvement in fuels and carriage should be investigated.

The presentation of the current situation for forestry in steep terrain shows that improvements are required for the activities of working with a chainsaw, hand delivery of timber and cable extraction.

The results of the carbon monoxide measurements and the literature with regard to fewer harmful substances indicates the need to introduce special fuels into forestry. Currently in mid-Europe the law and the very high price restricts the introduction. The complete discussion could be brought onto a operational basis if in future research the cancerous substances could be determined in the blood resulting from the various fuel types.

Job-rotation should be encouraged in forestry work. These measures are just a part of counteracting heavy work demand, but does not increase the individual workers capacity. Partially autonomous working groups such as those used in industry for a considerable time already should be implemented. This would require the need for new organisational measures for forestry work, wage systems and educational models. At the moment the desire to create these changes is still low.

Cable systems with mechanical slack pulling do not only increase the scope of implementation but also reduce the work load of the chokersetter. If possible two chokersetters should be used for all forestry activities on steep terrain. Even though payment is according to productivity, adequate rest breaks should be held.

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Work task	**Without**			**With**		
	mechanical slack-pulling					
	x	MIN (beats/min)	MAX	x	MIN (beats/min)	MAX
Radio control activity	37.9	0.8	72.6	34.7	3.0	59.9
Pulling the main-line	47.5	15.1	70.3	40.8	8.1	58.6
Helping prepare the load	43.8	18.1	64.3	37.4	14.9	55.7
Going in the terrain	36.3	11.1	65.5	34.1	6.5	58.2
Work delay time	25.3	7.0	60.6	22.5	3.3	52.0
Recovery time	23.3	18.0	34.3	4.7	0.2	28.8
Walk to rest area	61.0	61.0	61.0	29.5	18.1	47.7
Operational delay time	21.3	2.5	67.6	35.5	18.7	50.1
Personel delay time	27.3	25.6	45.6	0.0	0.0	0.0
Change-over time	45.5	17.4	62.7	39.8	25.9	54.7
Avoidable delay time	0.0	0.0	0.0	40.4	25.9	46.3
Other time	0.0	0.0	0.0	42.6	18.2	59.4
Mid-day break	23.2	23.2	23.2	8.5	6.3	10.7
Work time		37.6			34.8	
General time		29.6			25.3	
Total work time		37.0			33.4	
Rest pulse		66			74	
Over endurance limit (%)		57.9			51.6	
Under endurance limit (%)		42.1			48.4	

TABLE 2. **Work demand (work pulse) for the chokersetter when using a carriage with and without mechanical slack-pulling**

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An Ergonomic Study Of Motor-manual Felling In Thinnings

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ABSTRACT

One of the principal ergonomic problems in motor-manual thinning is that of trees hanging-up during felling. In this study on the occurrence of hang-ups in thinning of *Cryptomeria japonica*, stand conditions and the physical workload of manually removing hung-up trees and its limit were investigated. The probability of hang-ups tended to become greater with increasing height of the tree being thinned and increasing stand density of remaining trees. Manual handling of hung-up trees, e.g., pushing the tree by hand was the hardest work during felling as the highest heart rate was observed during this work. Some dangerous working movements were found in this work. The force required to remove a hung-up tree greatly affects the physical work load and work safety. The pushing force required to remove a hung-up tree varied widely with each tree in an even-aged stand. In conclusion, it is recommended that operators should acquire and use adequate accessory equipment and/or a small-sized winch for removing hung-up trees even in first or second thinning of *Cryptomeria japonica*.

KEYWORDS-- *Thinning, chainsaw, hang-up, physical workload, work safety.*

INTRODUCTION

The area of artificial forests in Japan, about 10 million ha, accounts for about 41% of the total forest area. The artificial forests, which need tending and/or thinning, occupy about 70% of the total artificial forest. Thinning is very important to improve the quality of artificial forests. The practice of thinning, however, has tended to be delayed recently, mainly because of a lack of demand for thinning logs and the increase in thinning costs. It is estimated that, in 1995, the area of stands thinned in Japan was just half of the total area of private forests which needed thinning (Japanese Forestry Agency 1997).

Advanced machinery such as harvesters or processors has been introduced recently in place of chainsaws, for thinning as well as final cutting (Inoue *et al*. 1994, Sakamoto *et al*. 1995). However, there are many mountainous forests in Japan where such machines are difficult to operate and so chainsaws will have to be used in these areas for some time to come.

The most serious problem in motor-manual thinning may be the occurrence of hang-ups, which occur because of the contact between a tree being felled and one, which is remaining. Once hang-up occurs, working efficiency decreases markedly while the removal of the hung-up tree is undertaken (Sakai *et al*. 1988). The manual handling of a hung-up tree seems to be one of the most strenuous and dangerous operations in forestry (ILO 1979).

In this study on the occurrence of hang-up in thinning of *Cryptomeria japonica*, stand conditions and the physical workload of manually removing hung-up trees and its limit were investigated.

METHODS

The thinning operations with a chainsaw were done in two artificial forests in the Iwate University Experimental Forest. The tree species was *Cryptomeria japonica*, the major plantation species in Japan. As shown in Table 1, the thinning operations were done in flat (3°) and steep (32°) terrain. The operator was an employee of the University Forest. He was 43 years of age with 25 years experience. The working process was recorded by a small video camera. A small data logger measured the operator's heart rates every 10 seconds during the operation.

Terrain condition	Flat terrain	Steep terrain
Average angle of slope	3	32
Species	*Cryptomeria japonica*	*Cryptomeria japonica*
Age of stand (years)	35	49
Thinning intensity (%)	32	28
Average DBH of removed trees (cm)	9.0	12.7
Average height of removed trees (m)	9.5	11.9
Average volume of removed trees (m3)	0.042	0.089

TABLE 1. Terrain and stand conditions of the study site.

The resistance force acting on the crown of a hung-up tree greatly affects the operator's physical workload during tree removal. However, it is difficult to measure the force during the operation at the same time. For this reason the force was estimated from measuring the tensile force when pulling a wire rope attached to a hung-up tree as shown in Figure 1. The measurement was done in two *Cryptomeria japonica* stands, aged 19 and 24-year-old.

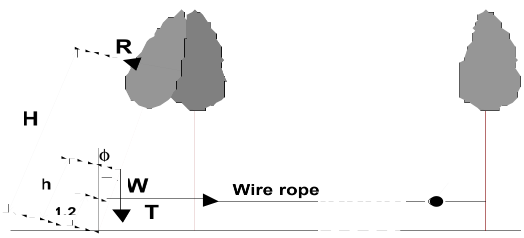


FIGURE 1. Forces acting on a hung-up tree

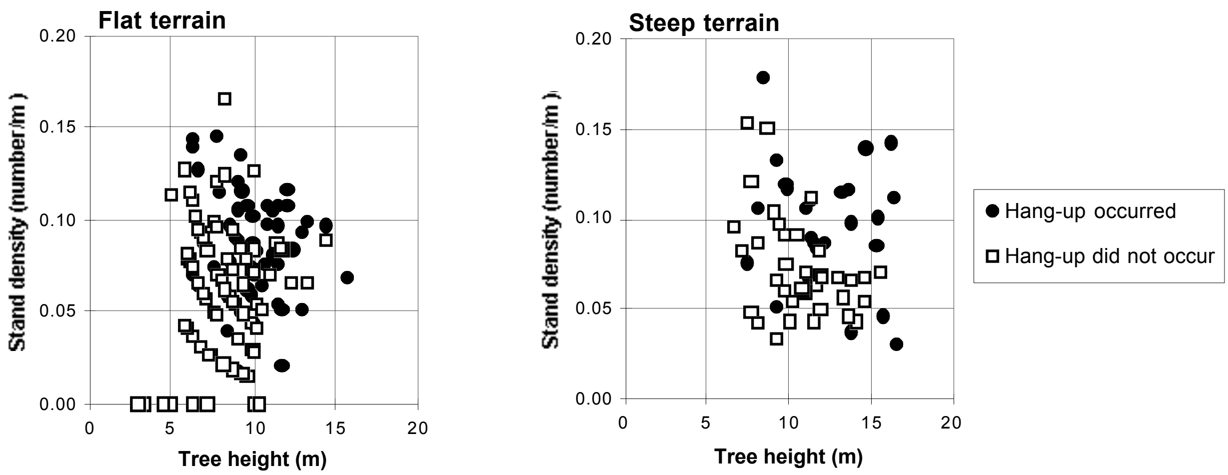


FIGURE 2. **Relationships between tree height and stand density**

RESULTS AND DISCUSSION

Occurrence of hang-ups

Table 2 summarizes the result of the felling operation.

Flat terrain	Flat terrain	Steep terrain
Felling (%)	33.6	22.0
Moving (%)	40.8	39.1
Removing hung-up trees (%)	25.6	38.9
Total (%)	*100.0*	*100.0*
Number of thinning trees	149	101
Number of hung-up trees	60	52
Percentage of hung-up trees (%)	40.3	51.5
Operational efficiency (m3/hr)		
Hang-up did not occur	4.28	5.73
Hang-up occurred	2.94	2.75

TABLE 2. **Results of felling operations**

The percentage of the time for removing hung-up trees was 26% for flat terrain and 39% for steep terrain. The percentage of hung-up trees was 40% for flat terrain and 52% for steep terrain. Both the percentage of the time for removing hung-up trees and the percentage of hung-up trees were greater for steep terrain than for flat terrain. When hang-ups occurred, the operational efficiency decreased by 31-52%.

Although various factors may affect the occurrence of hang-ups, the size of a thinning tree and the stand density of remaining trees around a thinning tree seem to be main factors. Figure 2 shows the relationships between tree height of a thinning tree and stand density of remaining trees around a thinning tree. The thinning trees which hang-up tended to increase with increasing tree height and stand density in both flat and steep terrain. Therefore the felling direction should be carefully planned, especially in densely stocked forests.

Time for removing hung-up trees

When the hang-up occurred, the operator first tried to push the trunk of the hung-up tree by hand at shoulder height. As shown in Figure 3, pushing the trunk of hung-up trees by hand was the method most often used (38-48%) for removing hung-up trees. The use of other methods depended on the condition of the hang-up. That is to say, they depended on the resistance force acting on the crown of the hung-up tree. When the resistance force was small, only pushing the trunk was applied. As the resistance force increased, another methods also were applied and a complicated work process for removing the hang-up could be seen. These methods included some dangerous working movements, e.g., felling the tree in which the hung-up tree was caught and cutting pieces of wood from the base of the hung-up tree.

Figure 4 shows the relationships between tree height and time taken to remove a hung-up tree.

When removing the hang-up by only pushing, removal times were below 15 seconds for flat terrain and 24 seconds for steep terrain. When other methods were included,

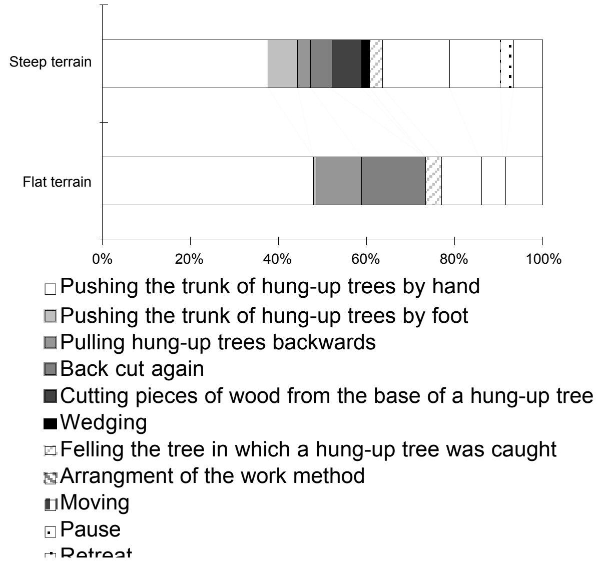


FIGURE 3. **Percentage of each work element for removing hung-up trees**

the removal times were widely scattered especially in steep terrain with trees more than 10 m tall. This may be because the difficult terrain condition affected the working movement for removing a hung-up tree.

Heart rate during removal of hung-up trees

Figure 5 shows the average heart rate during the operation. The average value was greater for steep terrain than for flat terrain. The difference was 19-21 beats/min. The average value was slightly greater when a hang-up occurred than when a hang-up did not occur. The maximal heart rate during removal of a hung-up tree in steep terrain was 144 beats/min, which reached the upper limit of "very heavy work" (130-150 beats/min) according to the classification of physical work load by Åstrand and Rodahl (1988). This shows that removing hung-up trees affects operator's physical work load especially in steep terrain, although moving between thinning trees may also increase the operator's heart rate.

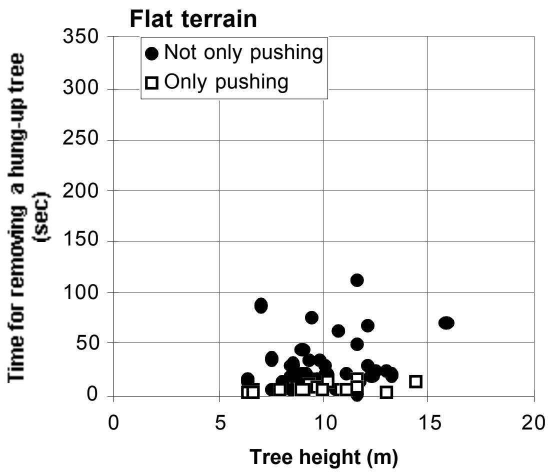
Figure 6 shows the relationships between tree height and average heart rate during removing each hung-up tree. When tree height was low, the heart rate tended to increase with increasing tree height. When tree height was 15 m or more, heart rate tended to decrease. This may be because the pause decreasing the operator's heart rate became longer with increasing the time for removal of a hung-up tree.

Force required to remove a hung-up tree

The maximal tensile force T in Figure 1 was measured when pulling a wire rope attached to a hung-up tree horizontally at a height of 1.2 m. Figure 7 shows the relationships between the height of a hung-up tree and T. The average value was 108 kgf in a 19-year old stand and 182 kgf in a 24-year old one. The average force was increased with tree age in *Cryptomeria japonica*. However, the tensile force varied widely with each hung-up tree in an even-aged stand.

As shown in Figure 1, the resistance force acting on the crown of a hung-up tree R can be calculated using the following formula:

$$R = \frac{(T \cdot 1.2 \cdot \cos\phi) + (W \cdot h \cdot \sin\phi)}{H}$$



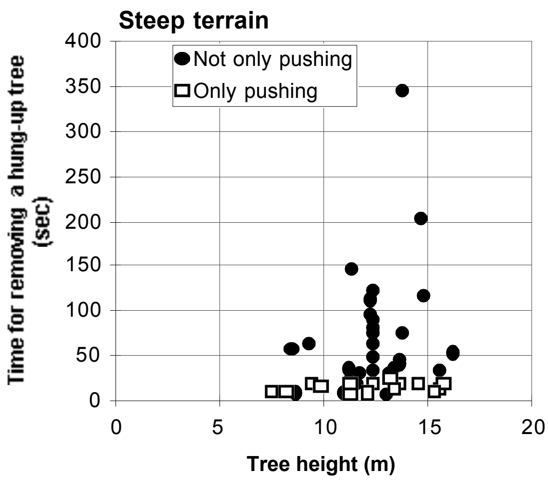


FIGURE 4. **Relationship between tree height and time for removing hung-up trees**

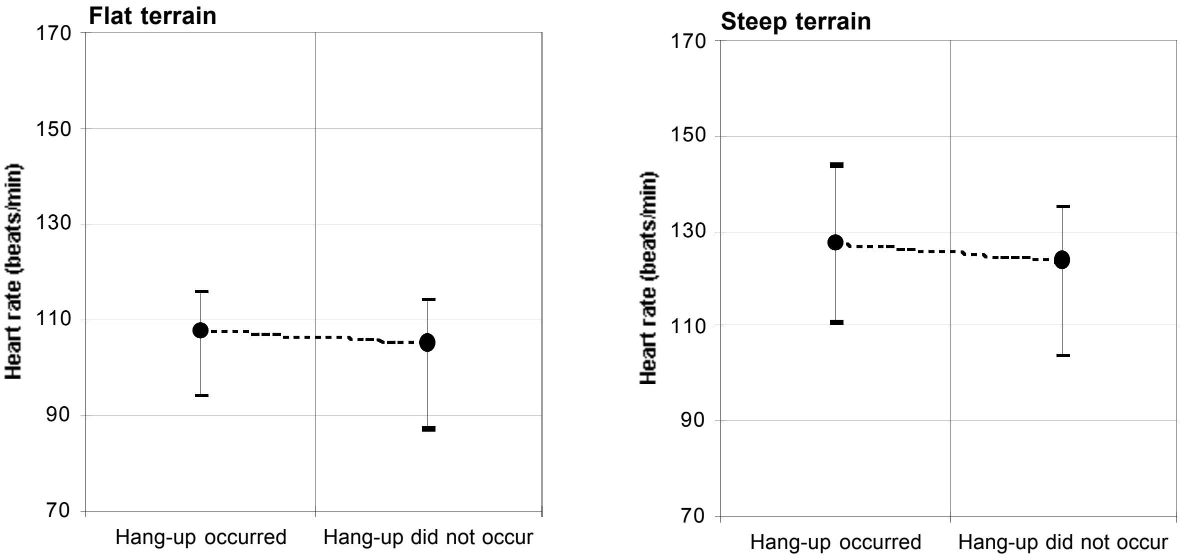


FIGURE 5. **Average heart rate during the operation per a thinning tree.**

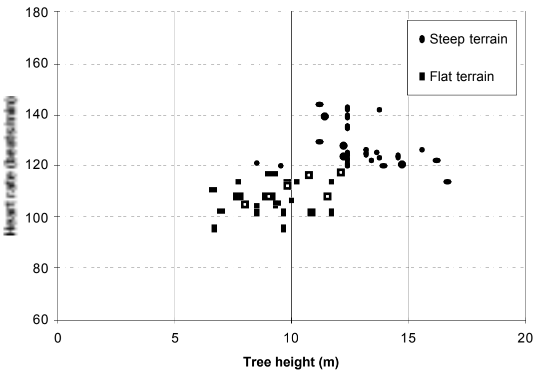


FIGURE 6. **Relationship between tree height and average heart rate during removing a hung-up tree.**

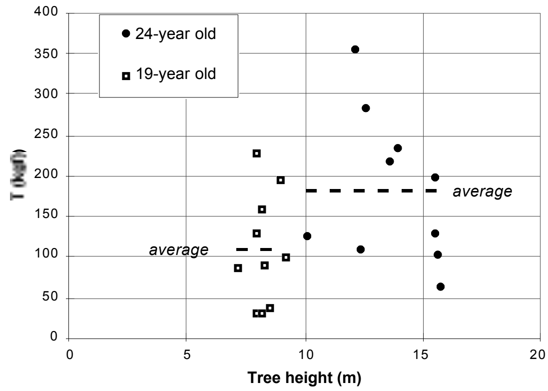


FIGURE 7. **Relationship between tree height and T.**

where W is the weight of a hung-up tree, h is the height of the center of gravity, H is the height of the acting point of R, and is the angle of a hung-up tree. Figure 8 shows the relationships between tree height and R. The average value was 32 kgf in a 19-year old stand and 36 kgf in a 24-year old one. The difference was so small as compared with T. Suppose that the operator pushes the trunk of a hung-up tree at a height of 1.2 m, the pushing force required to remove a hung-up tree is almost equivalent to the tensile force T. Therefore the average pushing force is estimated at 3.45 times as great as the average resistance force acting on the crown of a hung-up tree.

According to the measurement of the maximal pushing forces of Japanese adult males, the average continuous pushing force is 529 N (54 kgf) and the average instantaneous pushing force is 2390 N (244 kgf) at a height of 1.2 m (Kohara *et al*. 1986). As compared with these values, most of the values in Figure 7 exceed the average continuous pushing force. Some of the values in the 24-year old stand exceed even the average instantaneous pushing force. Therefore, depending on the condition of hang-up, it may be impossible for an operator to remove a hung-up tree only by pushing the trunk within his physical work capacity.

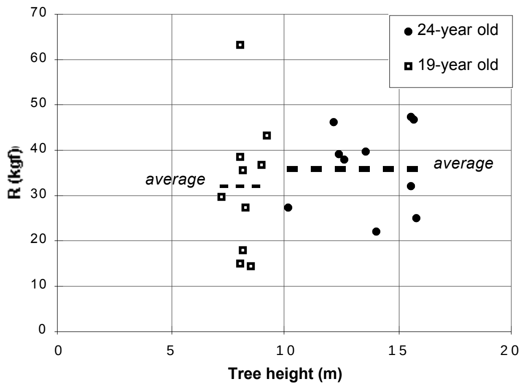


FIGURE 8. **Relationship between tree height and R.**

CONCLUSION

Maximal heart rate during removing a hung-up tree in steep terrain reached the upper limit of "very heavy work". Except when the tree trunk was pushed by hand, the methods for removing a hung-up tree included some dangerous working movements. However, the pushing force by hand required to remove a hung-up tree varied widely with each tree in an even-aged stand. Most of the forces exceeded the average continuous pushing force of Japanese adult males. In conclusion, it is recommended that operators should acquire and use adequate accessory equipment and/or a small-sized winch for removing hung-up trees even in first or second thinning of *Cryptomeria japonica*. Further research will be needed regarding hang-ups of various different tree species.

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Part 7

Interactions of Forestry and Rural Development

Forest Operations and Rural Livelihood Needs: the Case of Mount Meru Forests in Tanzania.

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ABSTRACT

Mount Meru forests are government owned and consist of both natural and man made forests. Official management objectives of the forests include water catchment, production of forest products and forestry training. The forests are surrounded by local communities whose high population growth rate has resulted in problems of land scarcity and increasing demand for forest products.

The paper examines problems faced by the management of Mount Meru Forests in trying to strike a balance between forest operations, environmental protection and the livelihood of the local people. Forest operations are geared towards achieving sustainable production of forest products and environmental protection. The local people, through illegal and indiscriminate harvesting and collection of forest products, overgrazing, encroachment and setting of forest fires, threaten the disappearance of the existing forests.

The paper is based on a survey which was conducted in randomly selected villages around the forests and interviewing key forest management stakeholders. Information on socio-economic, land use pattern, forest resources utilization, attitude of the local peoples towards forests and environmental protection was systematically collected and analyzed.

Results indicated that about 90% of the interviewed villagers have farms in the forests. Despite some of the farms being allocated to the local people after harvesting operations, illegal encroachment into the forests was still observed. In addition, villagers collect both forest and non-forest products from the forests while cultural activities take place in some specific sites in the forests. Lack of manpower, funds and necessary facilities to patrol the forests hinder the efficiency of forest guards to protect the forests against human and animal disturbances. The paper concludes that given the high demand for forest products by local people and the limited forest management capacity, joint forest management arrangements between the government and local communities should be considered as an option in addressing the current problems. The paper outlines some areas where the local community could effectively be involved in the joint management of these forests.

KEYWORDS--*Forest management, land use pattern, taungya farming system, forest and non forest products, logging*.

INTRODUCTION

Description of the area

Mount Meru forests are located on the slopes of Mount Meru in the Arusha region, northern Tanzania. The forests were gazetted as natural forest reserves in 1923 and cover an area of about 48,375 hectares (Moshi, 1997). They were managed for catchment and soil conservation purposes up to 1950 when about 8000 ha on the lower slopes of the reserve were converted to commercial plantations of exotic tree species managed by the Government Forest Service. Main tree species planted were *Pinus patula, Pinus radiata, Cupressus lucitanica, Eucalyptus maidenni, Eucalyptus grandis* and *Grevillea robusta*. However, planting of *Pinus radiata* and *Cupressus lucitanica* has now stopped due to serious attacks by *Dothistroma pini* and *Cinara cupressi* respectively (Tarimo,1996). In 1965, an area of about 14,000 ha on the upper slopes of the reserve was set aside for wildlife conservation under the Tanzania National Park Authority. Besides plantation forests producing timber, these forests were also meant to act as a water catchment area. In 1977, about 840 ha of the plantation forests were leased to Sokoine University of Agriculture (SUA) for training and research purposes. Thus, the present Mount Meru Forest plantation is composed of two entities, (90%) managed by the Forest Service and the other (10%) managed by SUA.

Topographically, the forests lie on the slopes of Mount Meru (4,562 m) which is an extinct volcano. The slopes are generally steep, gradients often exceeding 20% with some deeply dissected river valleys. The plantations run from 1500 m to 2500 m above sea level (SUATF, 1991). The general prevalence of steep slopes indicate a fragile ecosystem susceptible to soil erosion in the absence of vegetation cover. The volcanic soils are deep, fertile and freely drained making them suitable for agricultural crop production. The soils are very susceptible to soil erosion because they originate from volcanic ash hence they are light and loose (Lundgren, 1978). During the dry season, the exposed surface layer becomes extremely powdery and dusty, especially when loosened by livestock hooves or truck wheels. Incidence of soil erosion are common in the forest especially in areas without vegetation cover, along roads and cattle tracks. In some cases, such situations have led to development of deep gullies due to water erosion (Sawe, 1991).

Mount Meru Forests are bordered by a Game control area to the north and Arusha National Park to the east. As such wild animals sometimes cause disturbances or damage to the forests. The most common wild animals seen in the plantation are the colobus monkeys, blue monkeys and baboons. Monkeys feed on tree sap after debarking the upper part and hence cause tree damage especially in young cypress stands. Previously monkeys were controlled through shooting but due to lack of funds to buy ammunition the number of monkeys has been increasing steadily.

Over years, establishment of forest plantations has been through the Taungya farming system, whereby after logging activities are over, the clearfelled area is allocated to forest workers and villagers for cultivation of food crops. Low crops such as potatoes and beans are encouraged because they do not seriously compete with trees for light. Planting of trees is done under the supervision of the Forest Service while farmers continue cultivating their food crops at the same time, weeding and tending in their early stages of development. After a period of about three years (as the trees canopy start to close) farmers are supposed to abandon their farms and give room for the trees to grow alone. Although the system is beneficial to both farmers and the Forest Service, it needs proper planning and control mechanisms especially in areas of land scarcity like Arusha.

Problem statement and objectives of the paper

Mount Meru forests are managed for three main objectives; namely soil and water conservation, production of forest products, research and training in forestry. To achieve these objectives, sustainable management strategies have to be put in place, which should include protection of the forest against damages caused by human related activities. In recent years, protection of the forest against such damages has become a major problem to the extent of threatening continued existence of the forest and its productive capacity (Tarimo, 1996). The major human related problems encountered by the forest management team include overgrazing in the forests, illegal felling and debarking of trees, encroachment for cultivation purposes, and forest fires. As pointed out by Mattaba, (1997) livestock grazing in the forest used to be legal (by license) in the past. However, currently the activity has been banned because of the damages caused by the ever increasing livestock numbers. Illegal grazing in the forests is a common phenomenon in the area mainly because of a shortage of grazing land elsewhere. In extreme situations, livestock owners have resorted to grazing in the forests during the night. The grazing activity tends to increase the tension between local people and the forest management team. The taungya system, which is aimed at reducing cost for land preparation, weeding and access pruning has contributed to a range of problems in this area. Initially the taungya system worked well, but of lately the following problems have been identified and closely associated with the system (Tarimo, 1996).

- Scramble for farming plots leading to conflicts, nepotism and corruption in plot allocation.
- Selling and transfer of plots from one person to another without the knowledge of the Forest management.
- Over pruning of young trees in order to extend cultivation period.
- Deliberate uprooting of young trees in favour of food crops.
- Illegal cultivation in un-allocated areas including steep slopes and riverbanks.
- A shift from planting low growing food crops like potatoes and vegetables to planting maize which compete with trees for light in addition to demanding intensive weeding which lead to soil erosion.
- Preparation of farming plots using fire, which has in some cases spread to tree stands.

The above mentioned problems have had a number of observable impacts on the forests, the most conspicuous ones being:

- Poor stocking as a result of illegal cutting, illegal grazing and malpractices by taungya farmers.
- Deformed trees of poor quality due to damages caused by man, livestock, monkeys, and forest fires.
- Open areas created as a result of forest encroachment and uncontrolled harvesting accompanied with little tree planting.
- Soil erosion, especially in open areas, cultivated steep areas, riverbanks and along cattle tracks.

These problems and their impacts call for new thinking in the Forest Service which has so far focused on forest protection through continuous patrols by forest guards. Given the insufficient number of forest guards that would efficiently guard the forest and the nature of the illegal activities taking place in the forests (sometimes at night), involvement of local people could provide an option for future management of the forests. This study provides information on the socio-economic situation of the villages around the forests and the extent of dependency of these villages on the forests. The study also analyzes the potentials and limitations of involving local people in managing Mount Meru forests.

METHODOLOGY

Information for preparing this paper was collected through formal and informal interviews. A semi-structured questionnaire was designed and administered to two randomly selected villages surrounding Mount Meru forests. The surveyed villages were Shibori and Timbelo. In these villages, 50 households were randomly selected from the list of all households in the village to constitute the sample. The sampling fraction was 10%. Information on socio-economic situation, land use pattern, forest resources utilization, local people's attitude towards forest operations and environmental protection was collected through household interviews.

A separate questionnaire was designed to collect information from key forest management stakeholders. The stakeholders in this category included forest managers, field officers and village administrators. In total, 15 officers were interviewed under this category. Among other things, the interviews solicited information on stakeholders views on forest-people interface. Particular emphasis was placed on dependence of local people on forest resources for their livelihoods and the implication of this dependence on forest management decisions.

The formal interviews were supplemented with information collected through informal discussions at village and forest management level. Participant observation as well as secondary data sources provided some additional information on the key issues pursued during the study.

Both quantitative and qualitative data analysis was carried out. Data from the formal interviews was systematically coded and assigned nominal values for analytical purpose. The coded information was statistically analyzed using the SPSS computer program. For the purpose of preparing this paper, descriptive statistics and cross tabulations were considered in the analysis. Content analysis was employed in analyzing qualitative information collected through informal interviews/discussions. The results from these analyses are presented in the following section.

RESULTS AND DISCUSSIONS

General socio-economic situation

Meru forests are surrounded by villages inhabited mostly by the Waarusha tribe. The estimated total population is about 59,571 people. However, available arable land is only about 5500 ha indicating a high population density of about 1083 people/km^2. Subsistence agriculture and livestock keeping are the main activities of the villagers for their livelihood. Food crops grown include banana, maize, beans, Irish potatoes and a variety of vegetables. The only cash crop currently grown in the area is coffee. Because of land shortage, most of the food crops are grown in the forest plantations under the taungya system for home consumption. The surplus is often sold to generate some cash.

The main livestock animals kept include cattle, goats, sheep, poultry and donkeys. Raising of livestock is mainly by illegal free grazing in the forest plantation due to land shortage in the villages. In the Waarusha culture, possession of livestock in large numbers commands big respect and prestige because the animals are a symbol of wealth. Brewing of illegal liquor (locally known as gongo) and trading in forest and non forest products are other income generating activities done by villagers. Brewing is illegally done in the remote forest areas to avoid disturbances posed by the legal machinery and sold to both villagers and residents of nearby townships. Trading in forest products is usually done by unscrupulous, well-off villagers, who harvest trees from the forests illegally and transport the products to town centres for sale. Cutting and loading of wood is done by hired village paupers, mostly during the night when there are no forest guards.

Human and livestock population trends

The study revealed that both human and livestock populations around Mount Meru forests have been increasing over the years. Human population has been increasing at an annual rate of about 3.1% which is above the national average of 2.8%. The annual growth rate of livestock population has been estimated to be 4.3%. Table 1 presents the projected human and livestock populations in the study area.

Population	Year 1988	Year 1996	Year 2004	Average Growth rate (%)
Human	46,666	59,571	76,051	3.1
Livestock	74,665	104,566	146,442	4.3

TABLE 1. **Human and livestock population projections in the study area.** *Sources: Arusha Population and Family education office (1988): Arumeru District livestock office (1984): Arumeru District planning office (1997)*

The composition of livestock in the study area is made up of indigenous cattle (27%), dairy cattle (8%), goats (34%) and sheep (31%). On average, each household was found to support 8 people and ten livestock units, exerting much pressure on natural resources within and around the household.

Land use pattern

As mentioned earlier in this chapter, farming and livestock keeping are the main activities around Mount Meru forests. Cultivation of crops takes place both on family land and on forestland under the taungya system. On average each family owns about 0.5 ha of farming land in the village. With an average household population of about 8 people and 9 units of animals these small farm sizes can not support this population. Farmers are therefore compelled to cultivate on temporarily allocated plots in the forest plantations under the taungya system. About 90% of the surveyed households confirmed that they cultivate inside the forests. Allocation of plots is done by the forest management team in collaboration with village governments. Results from the survey indicated that on average the size of plots cultivated by villagers under the taungya system range from 0.25 to 0.5 ha. The main crops cultivated include maize, irish potatoes, beans and vegetables. About 80% of the interviewed farmers were in support of the current system of joint allocation of taungya plots while 20% were of the opinion that this activity should be handled by village governments only.

Encroachment into protected natural forest areas (i.e. along riverbanks and steep hilly areas) for farming land is a common phenomenon in the study area as a result of land scarcity and high population growth rate. This encroachment poses a threat to the existing forests as it results in soil erosion and landslides especially along riverbanks.

Keeping livestock was found to be another threat to the forests because livestock keepers illegally use the forests as grazing areas due to land scarcity. On average each household owns about 4 cattle, 2 sheep, 2 goats, 5 chickens and 1 donkey. In the studied villages some areas were set aside as communal grazing lands but these areas are small and far from the homesteads in order to avoid livestock damage to crops. Nearby forests therefore fall victim to grazing. Although illegal grazing in the forests is widely observed in the area, only about 22% of the respondents admitted that they graze in the forests. The remaining 78% reported that they either do not graze their animals or graze them on private and communal grazing lands. Only about 20% of the respondents confirmed that they use their animals for ploughing and transporting farm produce. Asked if they were willing to pay some fees for grazing animals in the forests as well as reduce the number of animals, the majority of respondents (70%) did not see any need for this kind of arrangement because they consider themselves as having few animals compared to what their culture encourages them to have. However, about 20% of the respondents thought that this was a good arrangement compared to illegal grazing while 10% did not have a comment on the proposed arrangement.

Forest products and services to local people

As the study strived to establish dependency of local people on forest products and services, much attention was given to building materials, fuelwood, non timber forest products, cultural functions and other values of the forests to surrounding communities. The following sections present the main findings in relation to these forest resources.

Building materials and fuelwood

Results revealed that while all the surveyed households purchased construction lumber from a range of dealers, they collect building poles from the forest free of charge. Both softwood and hardwood species are used for construction purposes. Fuelwood and withers are also collected from the forests especially from clearfelling sites. Table 2 presents respondent's opinions in terms of availability of building materials and fuelwood.

	Responses	
Materials	**Problematic**	**Not Problematic**
Supply of fuelwood	-	100%
Supply of building materials	12%	88%

TABLE 2. **Respondent's opinions on availability of building materials and fuelwood.**

It is evident from Table 2 that most villagers do not perceive the supply of fuelwood and building materials to be problematic mainly because they can collect them from plantation forests where various operations such as thinning and clearfelling are taking place. Those who think that the supply of building poles is a problem base their arguments on the fact that one has to get permission from the forest management before collecting the materials. Some argue that the supply is decreasing following recent attacks of cypress aphids (*Cinara cupresii*) to cypress stands. However, asked if they were ready to establish their own woodlots in order to ease pressure on the forest only about 23% of the respondents indicated that they were willing. About 10% of the respondents indicated that they were ready to plant trees around their farm boundaries especially if they could be supplied the seedlings. The main reason for the unwillingness to establish private wood lots or planting trees in the farms was land scarcity as illustrated by small farm sizes.

Non timber forest products and forest destruction

Villagers also depend on non-timber forest products from Mount Meru forests. This dependence was illustrated by the collection of a range of medicinal plants, bush meat and honey. Wild animals including monkeys, elephants, wild pigs, and buffalo are found in these forests. While monkeys are more common in forest plantations, the other animals are mostly found in the natural forest bordering the Arusha National Park. Some villagers hunt some of these animals (mostly illegally) to obtain bush meat for household use and sometimes for sale. Most respondents reported that the number of wild animals in the Meru forest has been decreasing over years due to habitat destruction and illegal hunting. In general, wild animals cause destruction to both agricultural crops and exotic trees in forest plantations through debarking. Destruction to forests has also been augmented by human activities especially in form of charcoaling and deforestation which result from encroachment farming.

With regards to honey collection and beekeeping, the results indicated that some farmers collect honey from the forests while few (about 20%) engage themselves in beekeeping activities in their farms. For the reportedly few farmers who have beekeeping enterprises, they usually use the traditional log beehive made from tree species such as *Cordial abycinica* and barks *of Cupressus lucitanica.* The average yield of honey from beekeeping activities was estimated to be about 15 litres per hive per year. The average price for one litre of honey was Tshs 1000 (1 US$ = Tshs 600). Honey is mostly used by local people in brewing, as for food and for medicinal purposes. Unfortunately most beekeepers and honey collectors use fire during honey harvesting thus increasing the risk of forest fires.

Cultural, micro-climate and other forest values

It was reported that forests are used as a panacea for performing cultural rituals such as rain making in specified forest sites which have been established from time immemorial by the households ancestors. Table 3 presents a summary of the villager's responses to questions which inquired whether a particular household was using the surrounding forests for cultural purposes and if villagers were aware that they are restricted from performing cultural activities in the forests.

	Responses		
Question	**Yes**	**No**	**Know others**
Involved in cultural activities?	70%	20%	10%
Aware of restrictions?	45%	55%	-

TABLE 3. **Household involvement in cultural activities and perceptions on restrictions.**

Results in Table 3 reveal that while the majority of households are involved in one way or another in conducting cultural activities in the forests, about 20% of the surveyed households are not involved in these activities mainly because they are Christians. The results also indicate that about 45% of the respondents were aware of the restrictions posed by forest management on pursuing cultural activities in the forests while the remaining 55% were not aware of the existence of such restrictions.

The study also revealed that respondents were aware of the fact that the forest played a vital role in the maintenance of micro climate. This was evident because respondents associated the observed decreasing quantities of rainfall over years and irregular rainfall patterns with deforestation and forest fires. All respondents confirmed their awareness on the usefulness of forests for recreational purposes such as hunting, picnicking, resting during high temperatures and educational activities such as training and research.

Potentials for local participation in forest operations

The study tried to solicit villager's views on the possible ways through which local people could participate in forest operations in order to improve their welfare and raise their morale in protecting the forests. Among the considered options were:

- Using local people's livestock (oxen and donkeys) in skidding operations.
- Contracting village government to harvest and sell forest products such as building poles, fuelwood and logs to villagers.
- Contracting villagers to guard the forests against encroachment, forest fires and wild animals.
- Involving villagers in decision making in all forest management operations.

Results indicated that although most of the respondents (80%) were supportive to these new ideas, about 10% of the respondents were hesitant, especially on the issue of contracting village governments to harvest and sell forest products. They claimed that this could bring some misunderstandings and corruption at village level unless it was well planned and supervised by forest managers. All interviewed households saw the need of involving village governments in the decision making process and to increase awareness on the importance of forests at village level.

Current forest management capacity

From the interviews, formal and informal discussions carried out between the research team and forest managers/officers involved in forest management, it was revealed that due to the existing economic hardships in the country it is not possible to employ as many field staff and forest guards as required. The employed field staff and forest guards are not motivated and lack the necessary facilities such as transport and field gears. It was revealed that forest managers only receive about 45% of the annual budget they request for running field operations.

This situation has crippled the current forest management capacity especially in undertaking the necessary forest operations and protecting the forests from destruction by local people. For example, it was revealed that annual planting operations had been reduced by 50% while harvesting had increased as a result of higher demand for forest products as well as the need to salvage aphid infested trees. This trend coupled with poor tending operations and inadequate protection of the existing forests threaten the sustainability of Meru forests.

CONCLUSIONS AND RECOMMENDATIONS

Previous sections of this paper have expressed that the current forest management strategies have failed to effectively protect Mount Meru forests. The paper has also illustrated how dependent local people are to the existing forests and the threats caused by this dependency. Due to both human and livestock population increase and lack of both human and financial resources to curb these threats, the need to change the current forest management strategies and local people's attitudes towards forests is eminent.

The paper therefore views joint forest management between the Forest Service and the local people as one of the possible options in addressing the current situation. Experience from other parts of the world has shown that the right to access forests and derive benefits from it is a major motivation for local people to participate in protecting forest reserves in their neighbourhood (Gronow and Shrestha, 1991; Davies and Johnson, 1994). Although taungya farming system has been allowed on a defacto basis, collection of withers and other minor forest products has often been regarded as illegal.

The paper identifies the following options as entry points if the Forest Service intends to pursue joint management initiatives with local people:

Contractual taungya farming in the forest plantation

Under this arrangement, the Forest Service would enter into a written legal agreement with villagers allowing them to grow food crops in the forest under certain legal terms as opposed to the current state of verbal agreements. This agreement should be binding to both parties and procedures for punishing offenders have to be laid down through joint discussions between village leaders and forest managers. Cultivation should only be done in clearfelled areas earmarked for tree planting the following year. Growing of food crops should be restricted to beans, potatoes and vegetables only. To minimize malpractice, allocation of farming plots should be done jointly by the Forest Service and village governments. Village governments should be charged with the responsibility of tending, pruning and protecting trees in these plots while the duty of the Forest Service could be reduced to offering technical advice, monitoring and control of these operations.

Contractual collection of minor forest products

This would involve granting villagers free access to certain areas of the forest for the purpose of collecting withers and other minor forest products free of charge through elaborate contracts. Grazing in the forest reserve should however be abolished but villagers might be allowed to cut grass in the forest especially along the fire lines for their livestock. Multipurpose tree species could be planted in fragile areas not suitable for commercial tree planting as part of the contract in order to provide fruits and fodder for livestock in addition to protecting soil erosion. Under such arrangement, villagers could be responsible for managing such areas under close monitoring by the Forest Service.

Contractual timber harvesting in the forest plantations

Currently timber cutting is done manually using two man cross cut saws and chainsaws while agricultural farm tractors fitted with winches, hand sulkies and oxen are used for skidding logs in the forest. Due to unavailability of capital to replace the ageing machinery, the trend now is to use manual or semi-mechanised logging methods in harvesting timber in most forest plantations in Tanzania.

Since the local people own oxen and an investment on the cutting tools, hand sulkies and other logging accessories is insignificant compared to the machinery, the Forest Service could enter into a contract with the surrounding villages so that logging is done by the local people while the Forest Service provides on the job training, the necessary gear (at a cost) and supervises these operations. Experience from the on going ox-skidding project in these forests (Abeli, et al, 1996) shows that farmers are willing to use their animals for skidding logs and both the farmers and the Forest Service are benefiting from this arrangement.

As concluding remarks, joint forest management arrangements alone can not address all the problems associated with the demand for forest products and services. Deliberate actions need to be taken to ease the supply of forest products at the household level and reduce the pressure exerted on Meru forests. The paper proposes enhanced farm forestry and agroforestry extension efforts as necessary complements to the recommended improvements in forest management. Due to small farm sizes, these activities should concentrate on farm boundaries and encourage the planting of multipurpose tree species in village farmlands.

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Socio-Economic Impact of Forest Operations in Mangdechhu Forest Management Unit, Zhemgang, Bhutan

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ABSTRACT

Sustainable resource use is a goal that tries to integrate economic and social development while maintaining the capacities of natural resources. Implementation of Forest Management Plans always results in positive as well as in negative social and environmental impacts. In Bhutan there is only little knowledge about the interactions of Forest Management and impacts. The present study aims (1) to investigate the effects of Forest Management on local communities, and (2) to understand their local perception.

A survey study was carried out in the Mangdechhu Forest Management unit interviewing more than one hundred households in six villages. Additionally village meetings were used to gather information on the community level. The study results in interesting findings. Local people feel that the local availability of forest resources decreased since the introduction of Forest Management. The Forest sector is important for local employment: 35% of the local households gain some income from forestry activities raising their living standard. Hunting restrictions lead to high game damages, and in some cases logging activities did not respect the value of spiritual sites. In the future studies on alternative land use systems and the establishment of community forests could help to fulfill the needs of local people.

KEYWORDS—*Social impact, environmental impact, socio-economic impact, forest management..*

INTRODUCTION TO THE STUDY & METHODOLOGY

Background and objectives

It is the over-riding objective of the Royal Government of Bhutan to protect the valuable natural resources of the country by utilizing them in a sustainable way. It is also acknowledged that this is the responsibility of the Royal Government of Bhutan and the local communities, and that this objective can not be achieved without involving rural communities in the management of forest resources.[1] To assure this, an increased attention for monitoring and evaluation of impact of forestry activities can be found, both within the FSD at the national level as well as within the Zhemgang District Administration.

These developments also formed the basic motivation for this impact study. It is meant to be practical to respond to a concrete need in a relatively short time. For its justification, we like to refer to the words of the Joint Secretary of Forests:

“For achieving the Royal Government of Bhutan’s policy of sustainable management of forest resources in the Kingdom, it is important that all activities carried out within the Management Units are environmental friendly and should also contribute to the socio-economic uplift-ment of the Bhutanese people.” [2]

Several studies have looked or are looking into the environmental aspects of management operations. Assessment of the environmental impact of forestry operations has already become a standard practice during management plan preparation, as well as during monitoring activities. However, so far, no studies have been undertaken to probe the impact of operations in the Forest Management Units on people, both directly and indirectly, both positively and negatively. In the monitoring of activities in FMUs, the socio-economic impact is also an issue, which, till date, gets relatively little attention.

It is often assumed that the Units only have a positive impact on the local population, by generating income and employment, while making forest products more accessible to the people. But so far, little is known about the actual impacts, both in terms of income and employment, and thus there is a need for some quantification. At the same time, from discussions in a few villages, it has become clear that the impacts of a FMU are not always positive. Some people have expressed concerns about their access to certain forest products, both wood and non-wood.

Therefore, a study looking into the impact of the FMUs was considered necessary. The study will seek the perspective of the local people who are directly affected by the presence of a forest management unit. Hence the following main objectives:

- To gain more insight into the actual (and potential) socio-economic benefits of an FMU for the local population;
- To come to a better understanding of the local perceptions of the FMU;
- To translate findings of the research into recommendations for improvement of the management of the units, and in particular the Mangdechhu Unit.

As an additional future objective, the methodology of this study might be evaluated in a later stage for the use in other units and as such might lead to a standard used for socio-economic data collection for the preparation of Forest Management Plans and for evaluation of FMUs.

Research questions

Based on the above stated, the leading hypothesis for this study is as follows.

“ Forest management units have both positive and negative impacts on the local population, in terms of employment, income generation, access to and control over forest produce and services, and social relationships, etc. Understanding these impacts is crucial for a holistic and sustainable management of Bhutan’s forest resources. ”

The challenge of the study was to verify and quantify this hypothesis. Therefore, the following research questions were formulated:

For all households inside or immediately surrounding the FMU:

- What is the history of access to, control over and availability of forest products, before the Forest Management Unit was established? (including tenure)
- How have access to, control over, and availability of forest products and services been affected since the Unit’s establishment? (including resource tenure, customary and official, like tsamdrog, sokshing)
- Could households list other both positive and negative impacts of the unit?
- For each of these impacts, could they be quantified?

1. Ministry of Planning, "Main Document," Eighth Five Year Plan (1997-2002), vol. 1, (Thimphu: RGoB, 1996) 98-105.
2. Sangay Thinley, "Foreword," Monitoring Forms for Forest Management Units, (Thimphu: FRDS, 1994).

- How do the households perceive the overall impact of the presence of the forest management unit? (Are they "better of"?)
- What expectations did and do people have from the Unit?
- Are there any changes in management, people would like to see?
- For those households in the FMU involved in forestry operations or related activities:
- What percentage of the households in or directly surrounding the forest management unit are directly or indirectly employed in forestry operations. (Logging, transport, sawmill, carpentry, etc);
- How much do they - on average - earn through this employment, both in absolute and relative terms (what percentage of household income is forest related)?
- What are the characteristics of the households involved - as opposed to those not involved? ("What made these households go into logging?")
- How do employment and income affect the households' livelihoods, including possible effects on division of labor in the household and/or village?

By way of conclusion:

In which way and to what extent does the forest management unit contribute to the socio-economic upliftment of the people?

Methodology

One forest management unit (Mangdechhu) has been be selected for the following reasons:

The fact that Mangdechhu Unit has been operational for some seven years implies that there has been a clear impact on the population.

Many basic data on income and employment are available on the villages in and around this Unit, thanks to the "Socio-economic baseline survey of Zhemgang District, 1994". These were readily available for use in this study.

The management plan for this unit is currently being revised. Therefore results of the study could be incorporated during the preparation of the new plan.

The availability of the research capacity within the Zhemgang District Administration, through the ISDP technical support.

Secondary literature was reviewed, as far as available. Main sources were the Baseline Survey of Zhemgang District (1995), the Management Plan for Mangdechhu FMU[1], and data from Zhemgang Range Office.

There are five villages located within the unit's boundaries, namely Tintinbi, Tama, Berti, Tshanglajong and Zurphe, and one right on the border (Goling). These villages were targeted for the survey.

Guidelines for village meetings and household-questionnaires were designed and one day tested in the field. Experiences from the field teams were evaluated and incorporated in the final versions of the village meeting guidelines and the household questionnaire.

In each of the six villages, PRA-methods were used in the introduction and group interviews during the village meetings. From the six villages, all households have been interviewed making use of the household-questionnaires. It was attempted to get both male and female respondents, as well as younger and elder household members. The fieldwork took around three weeks from 22 up to 31 October 1996.

For processing of the data, a database was designed in which all data of the interviews were entered. Subsequently, the data were processed and analyzed (making use of Microsoft Access). Detailed data may be found in a special report[2]. Detailed figures on the village meetings can also be found there. Copies of this report are available with the Forest Resources Development Section, the Zhemgang Dzongkhag Administration, the Zhemgang Range Office, and SNV-Bhutan.

To record and analyze the quantitative data, different methods were used. In the case of yes/no questions, the totals were just added. The same holds true for figures, e.g. family size, income, etc. If people were asked to indicate an increase, decrease, or no change in certain matters, the respective values of 1, -1, or 0 were given. In the analyses, these values were all totaled resulting in a score.

GENERAL BACKGROUND INFORMATION

Forest Management in Bhutan

Since the eighties, the FRDS has been developing plans for the scientific management of forests in Bhutan. There has been a clear development over the years from Working

1. Sangay Wangchuck, Mangdichu [sic] Management Unit Plan 1989 - 1998, (Thimphu: FRMD [now FRDS] of FSD, 1989).
2. To maintain the privacy of the interviewees, all households have been identified with a general ID-number instead of publishing the household and thram numbers.

Schemes focussing on sustainable commercial logging operations to holistic Forest Management Plans, taking into consideration all the various functions of the forests.

A total of ten working schemes have been developed over the time, of which still some are under operation and others have expired and work stopped. Till date, eleven Forest Management Plans have been developed out of which nine are currently being implemented with the help of Operational Plans. Twelve more Forest Management Units are identified. For some of these, the Forest Management Plan is under progress or almost finalized.

The participation of the local communities in the planning and implementation phases and their role in monitoring and evaluation is becoming increasingly important and is expected to increase even more in the light of the Royal Government of Bhutan policy for the Eight Five Year Plan .

Mangdechhu Management Plan

Mangdechhu FMU lies about thirty-five km from Zhemgang towards Gelephu along the national highway. The main rivers within the unit are Mangdechhu and Bertichhu. The total area of the FMU is about 5,000 ha with an altitude ranging from approximately 500 to 1,500 m.

The unit has been operated under an old style Management Plan (working scheme) since 1989. The plan is valid for ten years up to 1998 and is going to be replaced by a Forest Management Plan, for which the forest inventory has already been completed. Before commercial logging started in 1989, no logging had taken place in the area except for local use and some salvage logging operations in Chir pine forests.

As per the Management Plan, the local people are not allowed to extract house-building timber from the forest since establishment of the unit in 1989. However, the right to collect dry firewood and other minor products including non-wood forest products is still there. Twelve kilometers of road were already available at the initiation of the plan, but the construction of another 12 km of roads is foreseen in the plan. The main silvicultural systems prescribed in the plan are Seed Tree System in Chir pine (350 ha) with an annual yield of 2,625 m^3 and Clear Felling System with plantations in broad-leaved forests (200 ha) with an annual yield of 3,685 m^3. Logging has been done manually and by cable crane system. For the plantations in broad-leaved forests, a nursery is prescribed with a capacity of 60,000 seedlings.

The Range Office Zhemgang provided the following information regarding the actual implementation of the plan up to date: [1]

Activity	Management Plan Prescription	Actual Implementation	Remarks
Road construction	24 km	32 km	Extra roads to open up Tama and interior parts of Berti to sustain production.
Volume harvested	63,100 m3	46,049 m3	Zurphe sub-unit has not been operated.
Chir pine	350 ha	240 ha	Seed tree system.
Broad leaf	200 ha	80 ha	No clear-felling in Zurphe.
Plantation	200 ha	80 ha	In clear-felled areas.

TABLE 1. Production figures of Mangdechhu FMU

This study will not monitor the actual achievements in terms of produced volume, road construction, etc. Therefore, figures of Table 1 are only for background information.

Household interviews

A total of 113 households (households) were interviewed in the six villages. This is 72% of the number interviewed during the Baseline Survey conducted in Zhemgang Dzongkhag during 1994. The main difference is because of the number of households interviewed in Tintinbi (10 compared to 47 [2] in the Baseline Survey for Zhemgang Dzongkhag [3]) .

An almost equal number of interviewees were male and female (respectively 57 and 56) with an average age of 41 years (min. 18 and max. 94). When asked for the position in the household of the interviewee, the response was as shown in Production figures of Mangdechhu FMU. Only a slight difference in the position was noted between female and male respondents. Whereas among the men there are more heads of households (82% vs. 64%), more of the women are oldest child (21% vs. 2%). Among the female interviewees there are none who are married into the household. In this area it is more common that the men move in with the women’s family. The average size of the households interviewed was 12 members (min. 2 and max. 34).

1. As per letter ZR/45/97/668 dated 26/08/’97 from the RO Zhemgang.
2. The Baseline Survey most probably interviewed many people in Tintinbi who were not resident there.
3. Marlen Arkesteijn, Socio-Economic Baseline Survey 1994 Zhemgang District, (Zhemgang: Zhemgang Dzongkhag / ISDP, May 1996).

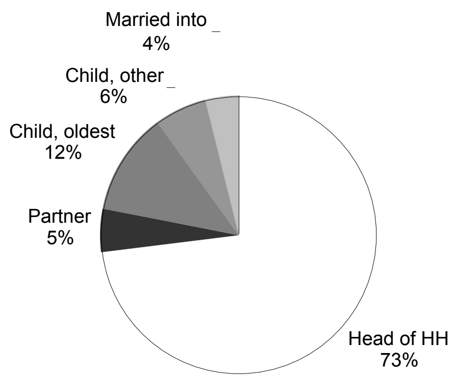

FIGURE 1. Position of interviewees in household

IMPACT OF THE UNIT ON THE LOCAL POPULATION

The information in this chapter is based on the village meetings and on the individual household interviews (113 in total).

Past situation and expectations

The overall picture of the past situation is one in which people were freer in their use of forest resources; they practiced more shifting cultivation in temporary settlements, let their cattle graze freely in the forest, and hunted freely. There was an abundance of forest products (wood and non-wood) of a generally good quality, usually nearby the villages. There were no or hardly any restrictions on the use of forest products, and no permits were required for felling timber. Trees were all felled and harvested manually which was time and energy consuming. In one village, people mentioned that at that time, people were not aware of the value of forest resources and of forest management. They added that there was more decay in the forest—due to absence of tree harvesting—leading to lost income opportunities for both the government and the local people.

Expectations that people had at the opening of the Forest Management Unit in 1987 were increased employment opportunities (during the slack season), increased income generation, improved transportation facilities, and an increase in timber availability along with a decrease in availability of other useful forest products, like for example mushrooms.

Forest use rights, availability of and access to forest resources

use rights

According to the survey, 92% of the households possess tsheri rights (Figure 2). In a decreasing number, they also

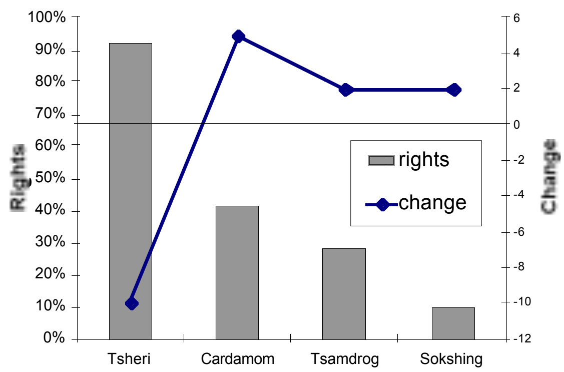

FIGURE 2. Forest use rights

posses cardamom, tsamdrog and sokshing rights. When asked for the change in rights over the past years, the most significant was a score of –10 for tsheri rights. The main reason given for the decrease was the forest act, which prohibits the cutting of trees older than twelve years. Some persons therefore have converted their tsheri lands into komshing. Only one person indicated to have planted walnut trees in expectation of registration as private forest. The other rights saw a slight increase over the years.

Looking at the average area people have under rights at present [1] (Figure 3), Tshanglajong is on the very low side with a total of only 2.5 acres and Tintinbi on the extreme other side with 86.9 acres. In Tintinbi, however, this can be ascribed to four very large right holders with tsamdrog rights of 100 to 300 acres.

Availability

In almost all villages, people mentioned a reduction in availability of forest resources as one of the main impacts of the unit, especially the availability near the roads (Figure 4). ‘Increased distance to forest products’, and ‘destruction of forest’ point in the same direction. In one village people also mentioned that nowadays there is less quality timber available (Average forest use rights by village in acres).

1. Averages calculated over the total number of respondents per village, including those without rights.

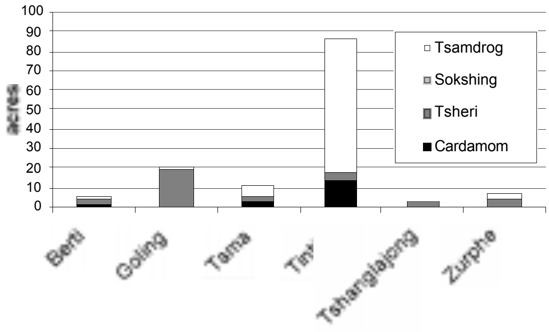

FIGURE 3. Average forest use rights by village in acres

For wood products, the main reasons given for decreased availability of timber are the increased population (35 respondents) and the logging activities (20 respondents). As a result, people have to travel farther these days to get their timber. For the other wood products, generally the same reasons are given for the decrease in availability.

For non-wood products, a general reason for less availability these days is the increase in population. For mushrooms, people indicate that not enough rotten materials are in the forests these days to stimulate the growth of mushrooms. During the village meetings and the household interviews, bamboo is said to be less available because of harvesting by contractors or other outsiders for commercial sales.

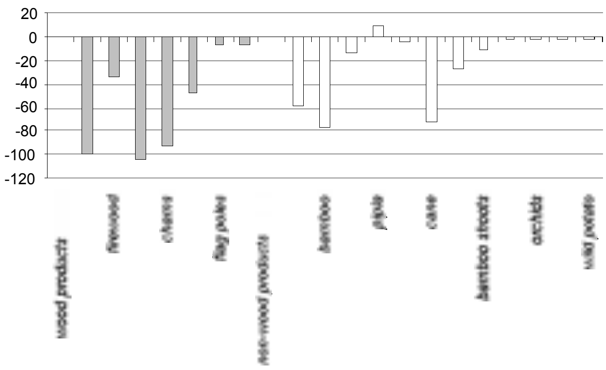

FIGURE 4. Change in availability of forest products (score)

Access

The access to forestland and products has reduced significantly over the past years. Restrictions have been imposed on use of tsheri (shifting cultivation) and tsamdrog (forest grazing), and for several forest products permits are required nowadays. One village mentioned an increase in royalties on timber from Nu 2 to Nu 69 per tree.

For almost all wood products, except flagpoles and dangchung, people indicate a decrease in access due to the payment of royalties. The most important changes are in timber, chams, shingleps, and fencing posts (in decreasing order of magnitude).

The only significant change in access to non-wood products can be seen in bamboo. Twenty-nine respondents said they now had to pay royalties compared to free access in the past. Adding the harvesting by contractors as mentioned above, the people have a hard time to get bamboo supply these days.

One village and few people remarked that nowadays there are fewer decaying tree stands in the forest, thanks to improved use and exploitation of the forest.

Economic impacts on the population

Village meetings

The most mentioned economic impact of the Unit is that 'ready made' materials have become available (from the sawmill or furniture house), saving time and labor. In one case, people added that this was only within reach of the 'wealthy'. Other impacts mentioned are an increase in off-farm employment and income, resulting in a higher living standard (better clothing and food) and a capacity to repay (BDFC) loans. Moreover, transport facilities have increased.

Employment

Of the total of 113 households interviewed, 39 households (35%) are involved in forestry related activities resulting in a total of 50 people (1 or 2 persons per household). The reasons given for engaging in these activities for almost all the households are to earn money and improve the well being of the family. The money earned is mostly a supplementary cash-income and helps to pay taxes, schooling expenses, other productive activities (shop, agricultural machinery), or is the only cash income source to cover basic needs. Sometimes people engage in forestry activities to recover loans from the BDFC. In several cases, people were convinced, or more or less forced by friends, rangers, or contractors, to join in logging activities. The households joining in forestry usually have sufficient labor available in the household.

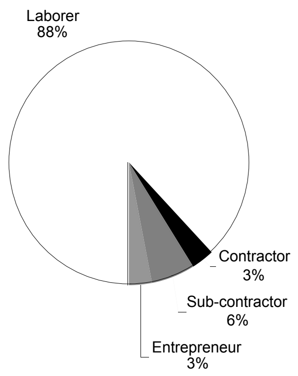

FIGURE 5. Terms of employment

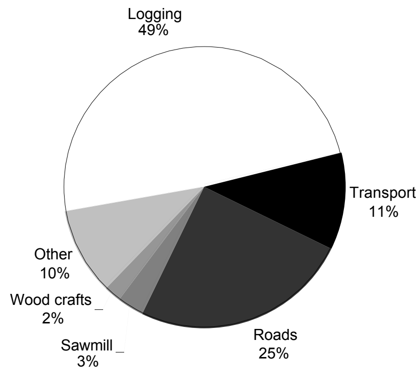

FIGURE 6. Activities of employment

The households not joining in forestry activities put "lack of labor/human power" forward as the most important reason for not engaging in forestry activities. This is commonly related to a heavy workload in agricultural, animal husbandry, and domestic activities, sometimes in combination with community service. Some families have members employed in the government or other services and do not feel a real need to get involved. A few indicate they earn sufficient income from agricultural activities.

The average age of the 50 people involved in forestry activities is 38 years. Of the total, only 5 are women, the rest men. The terms and activities of employment are given in Figure 5 and Figure 6. The average time spent in forestry activities is three months ranging from one month a year to full time employment. All the women are employed as laborers in plantation maintenance for only a maximum of three months in a year.

Income

The interviewees were asked to indicate their income from forestry activities if applicable and their total annual income per household. Per village, an average was calculated for forestry income, total income, and the percentage of the forestry income as part of the total income. The average was calculated over the total of respondents, so including the households with no forestry or other income. The resulting data was compared to the Baseline Survey for Zhemgang Dzongkhag. The results can be found in Table 2.

Although the figures can not be called authoritative, a trend in the income can be derived. The most interesting trend is that the importance of the forestry employment as income generating activity has significantly increased in two years (from May 1994 up to October 1996). With an increase of the total household income of only 7%, the increase in income from forestry activities is 127 %. Therefore the share of the forest-related incomes in the

	forest income		total income		forestry of total (%)	
village	**Mangdechhu**	**Baseline**	**Mangdechhu**	**Baseline**	**Mangdechhu**	**Baseline**
Berti	9,060	1,429	11,175	5,292	81%	27%
Goling	33	100	6,308	2,092	1%	5%
Tama	521	44	8,327	5,061	6%	1%
Tintinbi	37,940	7,298	68,396	32,648	55%	22%
Tshanglajong	1,328	483	9,192	4,287	14%	11%
Zurphe	4,030	74	7,690	4,171	52%	2%
total 6 villages	5,525	2,437	13,500	12,572	41%	19%
increase (%)		127 %		7 %		116 %

TABLE 2. Average income data compared

total household income has risen from 19% to 41%. The highest forestry incomes can be found in Tintinbi with a maximum as high as Nu 180,700 per year (Table 2).

Laborers and contractors

When asked whether wages paid in forestry activities are fair (compared to other employment opportunities), about half of the respondents said the wages are fair, especially compared to the past. If people responded "unfair", it is usually connected to specific problems, like not being paid in time or not at all. One laborer mentioned that the wages are unfair since in logging they get paid Nu 50/- per day only whereas other works pay Nu 60/- through Nu 70/ - per day.

Some laborers feel the contractors take too much profit and underpay the laborers. Some contractors complain that they face difficulty in getting advances from the forest office or having to go to Bumthang (DFO) to clear the bills. Some contractors feel the logging area is very steep and they have to pay high wages to the laborers. One respondent said the sub-contractors do not get enough money from the license holders.

Workload and division of labor

Out of the 39 households involved in forestry-related work (50 persons), only 8 households indicate an impact on the workload of other household members and the division of labor (all these respondents are men).

In case an effect on the workload and division of labor is reported, it is explained that there is a shortage of human power in the household or contributed to the cause that some tasks can supposedly not be taken over by females. In most cases, however, it is stated that there is no real problem because other household members take over the tasks of the one involved in forestry. Seeing these reactions from the respondents, there is some effect on the workload and division of labor since work is left undone till later and some tasks are handed over to others (mostly the wife). Seeing the number of 8 respondents out of 50 persons employed, the effect however does not seem to occur on a large scale. Several households solve the workload problem by engaging labor for the agricultural work (at Nu 40-50) while they earn Nu 60 in forestry.

Most households say there is no real impact on the household's workload since the work is done during the slack season (agricultural off-season). Quite some households also report an abundance of labor within the household, so they can spare one member for forestry activities.

Only 3 persons report an effect on the workload and division of labor on the village level. This is the case if the person involved in forestry is the only one of the household who can participate in community tasks (shaptolemi). In some cases, the household substitutes the community labor by payment or hiring others. In two cases it is mentioned that the person is unable to attend important village meetings due to the forestry involvement.

Standard of living

Of all the households involved in forestry, most feel that the forestry income has clearly raised the standard of living or well being of the household. Most indicate that their ability to buy clothes, rations, and utensils has increased. Improved housing and an increased ability to pay taxes and recover loans are other benefits mentioned. Lastly, some households mentioned children's education and establishment of orange orchards as benefits. If the increased income did not help to raise the standard of living, it was reportedly due to belated payments, to a high amount of taxes to be paid, or a large number of children.

Accidents

In the interviews, four accidents have been reported related to forestry activities leading to hospitalization for a period of five days up to eight months. Three accidents took place with villagers from Berti, the other with a villager from Zurphe. Two accidents were related to truck loading. One accident was related to the debarking of a log during which a rock rolled down on the hand of the person. One accident was related to chain saw operation (the person cut in his leg). In two cases, there was a complaint that no compensation was given by the contractor.

Other impacts

Fauna and flora

The interviewees have been asked whether they have observed any changes in wildlife or flora in the area in the past years. The only significant change reported by most households is a clear increase in the number of wild boars and of barking deer.

People mostly ascribe this to three factors, namely a decrease in the population of wolves and wild dogs, restrictions on killing, and the absence of hunters. The resulting effect is a strong increase in damage to agricultural crops, in particular maize and mustard (by deer) and maize and paddy (by wild boar). In one village (Berti), people reported a clear decrease in the number of wild boars due to the outbreak of a disease (ringworm and foot and mouth disease). A slight increase was noted in the number of porcupine and monkeys. A slight decrease was observed for the number of wolves.

Additionally, a decrease was reported for two tree species, namely Champ (Michelia champaca) and Lampata (Duabanga grandiflora). The reason given is the extraction by logging activities due to the high quality of the timber of both species. The result is that these species are hardly available anymore.

Watershed and erosion

During the village meetings, two villages reported that, as a consequence of logging activities, water sources had dried up or were otherwise affected. One village mentioned a higher incidence of landslides along the forest road. A positive impact brought up is that there is an increased awareness of the need for forest and watershed conservation.

In the household interviews, people were asked whether they have observed any changes in the water resources in the area or in soil erosion and what they would relate this to.

Related to watersheds, 68% report clear changes in the water resources. For most villages, a slight increase in quantity and some improvement in quality is reported. Berti is the only exception where an average of 29% report a decrease in quantity and a deterioration of the quality (Figure 7).

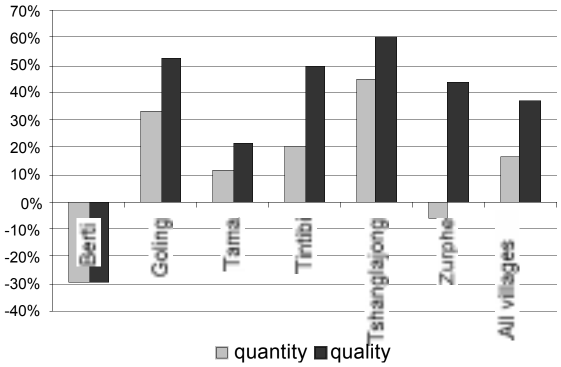

FIGURE 7. Watershed changes

In total 63% report signs of erosion. Reportedly most of the erosion is due to natural causes. The second cause for erosion is the national highway. Logging and forest roads account for only a very small percentage of the causes for erosion, except for Berti where 14% mention logging and 43% mention forest roads as the major causes for erosion. Although these small numbers are not very statistically significant, they give an indication for further attention and possible control of the problem. The same holds true for the other villages, where diverse causes have been given for erosion (figure 8).

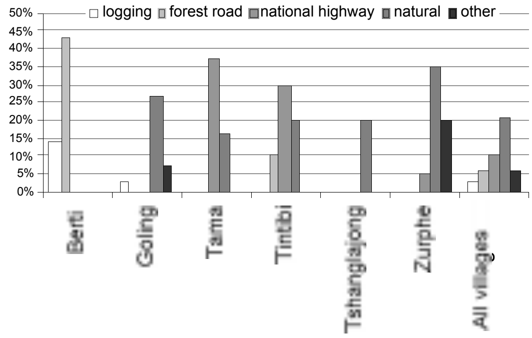

FIGURE 8. Erosion

Culture and other impacts

Traditionally people respect certain areas because of the presence of local deities (“Aila” or ”Menmo tshen”) by cutting no trees. Most villages list around five of such sites. Some of these are Bebigang near Berti, Ramaya, Rakphai, Bunanap, and Khaygang in Goling. Cutting of trees in such sites is believed to cause problems such as diseases or disasters.

Despite the local beliefs, quite a large number of respondents mentions that some cultural sites or values have not been respected in the forestry operations. One example is the Tong area. A respondent said that due to logging in that area, there had been a heavy disaster in the village. The number of this kind of cases reported is with 34% of the respondents quite significant and has to be given serious consideration.

A variety of other impacts have been mentioned by the people, of which most are positive but some negative (Figure 9).

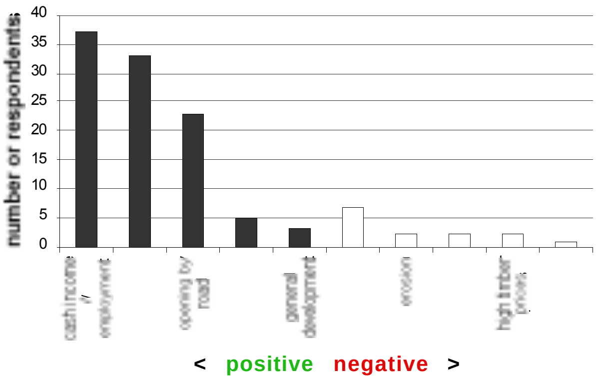

FIGURE 9. Other impacts

The main positive impacts listed by the people are the possibility to earn cash income, the availability of ready made materials and therefore the time savings in labor, and the opening by road which brings a lot of other possibilities for development and marketing of agricultural produce. The most important negative impact as mentioned by the people is the reduction of good timber species in the forest.

People's participation in forestry

During the village meetings, people brought up in two villages that they have become more involved in social forestry activities since the establishment of the unit. In particular in private forestry activities (tree planting on individually registered land), they are benefiting from a free supply of tree saplings. People also reported to take better care these days of community forests and small trees.

Internal meetings

Although only 36 out of 133 households mentioned that they use to have internal village meetings about forestry, it seems that in all of the 6 villages, such meetings have taken place.

In Berti, the tshogpa has called a meeting on forest road maintenance to divide the community into work groups who carry out sub-contracting work.

In Goling, the gup and tshogpa have been calling meetings on private forestry to coordinate private plantation activities.

In Tama, the tshogpa and mang ap have organized meetings with the Dzongkhag forestry staff to discuss the potential for community forestry. [1] The results of these meetings were negative in the sense that Tama was not selected as a pilot site. Some respondents blame this on a lack of cooperation among the villagers. The private forestry program, however, is ongoing and successful.

In Tintinbi, several meetings have been organized by the tshogpa on different forestry activities, like contracting work, community forestry, private forestry, forest fires, and cardamom plantations. Some of these meetings had positive and others negative results.

In Tshanglajong and Zurphe, the tshogpas have also been organizing meetings with forestry staff, mostly on private forestry and forestry rules and regulations. These meetings were considered positive. The private forestry program is ongoing and people are more aware of the importance of the forests.

1. Tama was one of the two candidate pilot sites for community forestry.

External meetings

All villages report having had external meetings about forestry with government officials. These were mostly conducted by government staff in the villages. Some of these were village meetings for the explanation of logging (allotment of coupes) and road construction activities or to raise awareness of forest rules and regulations. Others were personal contacts, mostly on private tree plantations or tree nursery works (raising of seedlings).

In more than half of the cases where there was such communication with government officials on forestry, people were very satisfied with the results. The most common problems encountered were untimely supply of seedlings and low survival rate in the plantations. In Tama, some people are unsatisfied with the fact that no community forestry has been initiated in their village.

Positive results are mostly appreciated in the private forestry act and in forest fire control. Related to the first, people express the benefit for their children in the future.

Overall perception of presence of the unit

Overall perception and suggestions

When the local people's suggestions for future management were discussed during the village meetings, three issues came up quite clearly:

- In five out of the six villages, the communities expressed their strong interest in taking charge of the logging activities, in their traditionally used forest area. Taking over this responsibility would also include taking care of the reforestation activities, and installing a community nursery.
- One of the reasons for this proposal, is the idea that local people would be in a better position to respect both environmentally as well as culturally sensitive areas in the logging operations (water sources, irrigation canals, roads, cultural sites).
- Local people want to have a 'preferential treatment' when it comes to the allotment of contracts for forest related work. This is however a current practice, which people like to see continued.

Other suggestions

Some other suggestions, which came up during the village meetings, are:

- The creation of community plantations and the start of community forestry;
- Increased conversion of tsheri land into private tree plantations (private forestry);

- Inclusion of (community) cardamom plantations in forest management;
- Extension of the current road network, or realignment to open up the communities, as well as improved road maintenance and transportation facilities;
- The application of more environmental friendly techniques, like cable yarding;
- Allowing people themselves to take logs to the sawmill for sawing;
- To maintain the logging activities for continued income generation.

Voice in forest management

During the interviews, half of the households indicated they would like to have a voice or say in forest management issues. In 10 cases this relates to private forestry. People would like to convert more tsheri land into private forest or they would like to raise a private tree nursery (Berti). In many cases, people want to have a say in forest management in order to preserve the forests for future generations and at the same time derive optimum benefits from it (Goling). Some go as far as stating that certain forest areas should be owned and protected by the villagers themselves for conservation and supply to the government (Tama). Four households in Tintinbi express their interest in learning more about sustainable forest management (especially the younger generation), since the forest is such an important source of living and income to them. Lastly, some people want more involvement in the selection of contractors and sub-contractors.

Conflicts

A total of only 9 conflicts regarding forest management were reported. Some had to do with forest users from outside the unit. People feel that they can not control or correct outside forest users since the forest is common property. The outside users will simply ignore what they say (this is especially the case in Tshanglajong). Another type of conflict is that between a contractor and individual laborers. These are all about belated payments or no payment at all (Zurphe). In only three cases of the nine reported conflicts, the final outcome or settlement was reported to be satisfying.

In better condition with the unit

When people were asked if they felt they were in a better condition with the presence of the unit, almost all replied that the unit changed their situation for the better. The explanations given were more or less the same as under other impacts.

Changes in forest management

When people were asked what kind of changes they would like to see in future management of the forest, the replies can be summarized in eleven different categories (Figure 10). The most important change the people would like to see is that the contracting works will be given only to local people. A lot of importance was also given to community management of plantations and forests. They also replied that in the future, more attention should be given to conservation of the forest. Related to the alignment of forest roads, several people suggested that during the alignment more attention should be given to the location of the villages.

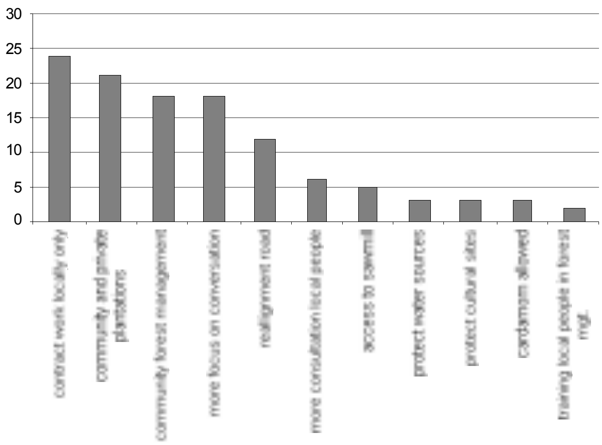

FIGURE 10. **Proposed changes**

CONCLUSIONS AND RECOMMENDATIONS

Past situation, forest use rights, availability and access

The fact that the people have become less free in the forest does not mean that the people are not satisfied these days. It was their expectation at the opening of the unit that this would result in many benefits, such as employment opportunities and improved infrastructure. However, not all expectations have been met. Instead of the expected increase in availability of timber, almost everybody reports a decrease, not only in timber but in all wood and non-wood forest products. However, the decreased availability of non-wood forest products was expected.

Although some people reported a decrease in tsheri rights, overall impact does not seem to be alarming (a score of – 10). Moreover, the government policy is that on environmental grounds shifting cultivation is to be phased out, with which a major start will be made during the 8th FYP period [1]. Therefore solutions to the perceived problem should focus on finding alternative landuse systems for people who possess tsheri rights.

The reported decreased availability of forest products can be attributed to different reasons. For timber and some other wood products, the main reasons seem to be an increase in population and the commercial harvesting. In light of the latest rules regarding logs and sawn timber, which put a ban on the export of these [2], there seems to be a solution for the time being since there will be an overabundance in logs and timber. Moreover, at least for the time being, the rural rates for logs and timber are assured.

On the long term, prices are expected to increase to a commercial level, which will have a definite impact on the access to certain products. The effects of this, however, can not be fully comprehended right now and will extend beyond the jurisdiction and responsibilities of the FSD. However, the FSD should monitor the developments closely and, in cooperation with the concerned government agencies, facilitate solutions for the rural people before they will be heavily affected. Although the present rates for timber from the sawmill are for some people already on the high side, the advantage of the availability of ready-made materials should be weighed against this. As people indicate, there is a big time savings involved in this, which they have available now for agricultural works or wage labor. Both of these will probably result in a financial benefit to them.

The increase in population is also given as the main reason for a decrease in the availability of most non-wood products. This is an inevitable development for which no solutions can be found. For mushrooms, people indicate that the current absence of rotten materials in the forest contributes to the loss of growth. Therefore, it is advised to maintain the coarse and woody debris in the forest by way of banning the extraction by charcoal manufacturers. To further maintain the rich bio-diversity of the forests, the marking and logging should be brought fully in line with the latest guidelines from the FRDS, such as the maintenance of snag trees and protection of buffers along streams and in between coupes. Although people considered it a benefit of the forest management to see fewer decaying trees in the forest, they could be made aware of the importance of these.

Bamboo is said to be less available to the local people because of intensive harvesting by contractors and other people from outside the unit. Since it is the objective of the FSD to give first priority to the local people in the utilization of the forest resources, it is advised to prohibit the harvesting of bamboo’s and canes by outsiders and to keep the utilization for local use only.

Economic impacts

The economic impact of the unit on the local people is quite substantial and seems to be growing with the forestry income covering 41% of the total income of the households. There is a direct impact through employment in forest related activities (35% of the households). Through the cash earnings, people are able to provide in their basic needs or more, pay schooling for their children, pay off BDFC loans, engage labor in their fields, etc. There are also indirect impacts, such as overall development of the area through possibilities for entrepreneurs and a better infrastructure for marketing of agricultural produce.

Although the response is limited (21%), it seems that there is some effect on the workload and division of labor. If the work is not left undone, it is mostly transferred to the wife, resulting in a higher workload for her. The effect on the village level is negligible.

Although the number of accidents reported are quite low (4 only), they should be given special attention. It is the responsibility of the FSD and especially the FDC to continue improving the safety and ergonomics in forest operations. It is therefore advised that a special working group will be set up within the FSD under the responsibility of the FDC to continuously monitor and improve safety and ergonomics in forestry. Labor conditions and responsibilities should also be looked into, since in two of the four accident cases there was no compensation from the contractor’s side.

Other impacts

The increase in the population of wild boars and barking deer is heavily affecting the people’s lives through the damage done to agricultural crops. However, this problem is not unique to the region and not a direct result of the forestry activities. The IPMDP is doing some research in Zhemgang especially related to the wild boar problem.

Two valuable tree species were reported to have significantly decreased in numbers, i.e. Champ (Michelia champaca) and Lampata (Duabanga grandiflora). Seeing the

1. Ministry of Planning, "Main Document," Eighth Five Year Plan (1997-2002), vol. 1 (Thimphu: RGoB, 1996) 57.
2. As per letter MOA/IX-35/141 dated 01/08/’97 from the Deputy Minister MoA.

value given to these species by the people, the FDC should give attention to this concern by including significant numbers of these species in the plantations.

The main problem with watershed changes and erosion seems to be in Berti. A significant reduction in water quality and quantity is given; some streams have reportedly dried up after logging operations. Erosion has reportedly been caused by the forest road. Although environmental monitoring will be part of the regular activities under the new management plan, action might be required at an earlier stage. It is advised that a professional team will visit the area to see if immediate action is required or if measures to be prescribed in the management plan will be sufficient [1].

The effect of forestry operations on cultural sites is significant. Of the respondents, one third (34%) reports that certain religious sites have not been respected during forestry operations. This kind of interference with the local beliefs should be avoided as much as possible. The new system of Forest function mapping developed within the FRDS should cover these kinds of areas in the future [2]. It is therefore advised when function mapping will be done for the new Mangdechouseholdu Forest Management Plan, these areas will be specifically mapped out and protected from operations according to the local beliefs.

The other impacts mentioned by the people are already covered by the previous topics.

People's participation in forestry

In all the villages, the gups or tshogpas have coordinated internal meetings related to forestry, sometimes involving the forestry extension staff. Although the outcome of these meetings is not always satisfactory to the people, the meetings seem to provide the right tool for especially information exchange. Meetings organized by government officials from outside focus most of the time on the same topics as the internal meetings. In 64% of the cases where there were meetings with government officials reported, the people were very satisfied with the outcome. Most of the appreciation and satisfaction goes to the Private Forestry Act. People are especially very interested in the establishment of private forests.

In Tama, people were dissatisfied with the fact that, after meetings about Community Forestry, Tama was not selected as a pilot site. It is therefore recommended that during the preparation of the Forest Management plan, special consideration will be given to look into possibilities of the establishment of a Community Forest. The information from the Dzongkhag extension staff gathered during the meetings could be used as a start.

People's overall perception and suggestions

It was suggested that during the tendering of contract works, the local people get priority. However, since this is already the current practice, it is recommended that this practice will be continued and monitored.

In the field of social forestry, several suggestions have been made related to Private and Community Forestry, conversion of tsheri lands, cardamom plantations, etc. These should be investigated and discussed by the Dzongkhag extension staff during village meetings.

The people especially expressed the benefits of improved infrastructure through forest roads. If new road construction is foreseen during the next plan period, attention should be given to the interest of the villages. Therefore, if with limited financial costs a new road can be diverted through a village, this should have the preference since it will greatly enhance the economic development of the concerned villages.

Since the new guidelines from the FRDS are much stricter regarding environmental protection (e.g. the banning of manual logging), the concerns of the people in this area will probably be addressed in the new Forest Management Plan.

People should be allowed to take their own trees to the sawmill as far as it is not in conflict with a sustainable and environmental friendly logging policy. The wish the people expressed that logging activities will continue in the future is covered by the fact that Mangdechouseholdu is selected as a new Forest Management Unit. However, new logging and other activities will be controlled more strictly according to the latest rules and guidelines and therefore will be more subject to social and environmental interests.

The suggestions regarding the people's voice in forest management have been covered already by the previous topics. However, increased attention should be given in all stages of forest management (planning, implementation, monitoring, and evaluation) to the opinion of the local people. This is, nevertheless, in line with the latest developments within Forest Management.

1. The team could be comprised of members from the FRDS (especially the officer responsible for the Management Plan), FDC, and possibly NEC with additional territorial staff from FSD and FDC.
2. Schindele, W. and D.B. Dhital, Forest Function Mapping and Planning within Forest Management Units, BG-SRDP Working Paper No. 11, (Thimphu, FRDS/GTZ, May 1997).

Although the number of reported conflicts is not very high, most of the cases were not satisfactorily settled according to the respondents. The FSD should aim for satisfactorily settling conflicts between the staff of the various sections (e.g. territory and FDC) and contractors.

Summary of recommendations

The following is a summary of the recommendations for Forest Management.

- A study on alternative landuse systems for tsheri.
- Close monitoring of the rural price developments by the FSD and, in cooperation with the concerned government agencies, facilitate solutions for the rural people before they will be heavily affected by the expected price hikes.
- Maintenance of the coarse and woody debris in the forest by way of strongly controlling and limiting the extraction by charcoal manufacturers.
- Further maintenance of the rich bio-diversity of the forests by bringing the marking and logging practices fully in line with the latest guidelines from the FRDS, such as the maintenance of snag trees and protection of buffers along streams and in between coupes.
- Prohibition of harvesting of bamboo's and canes by outsiders and keeping the utilization for local use only.
- Establishment of a special working group within the FSD under the responsibility of the FDC to continuously monitor and improve safety and ergonomics in forestry.
- Including significant numbers of Champ (Michelia champaca) and Lampata (Duabanga grandiflora) in the plantations by FDC.
- The visit of a professional team to Berti area to look into the watershed and erosion problems.
- During the Forest Function Mapping exercise, as part of the preparation of the new Mangdechouseholdu Forest Management Plan, a detailed mapping should be done for cultural and religious sites with special management prescriptions or protection from operations according to the local beliefs.
- Special considerations for the establishment of a community forest in Tama given during the preparation of the Forest Management Plan.
- A continuation and monitoring of the practice to give local people preference during the tendering of contract works.
- An investigation by the Dzongkhag extension staff during village meetings of the suggestions made related to Private and Community forestry.
- The diversion of future forest roads through villages if feasible with limited financial costs.
- Allowing people to take their own trees to the sawmill as far as it is not in conflict with a sustainable and environmental friendly logging policy.
- The FSD should aim for satisfactorily settling conflicts between the staff of the various sections (e.g. territory and FDC) and contractors.

ACKNOWLEDGMENTS

Thanks are first of all due to Dasho Sangay Thinley, Joint Secretary FSD, under whose authority this study could take place. Due to his supervision, the management of Bhutan's forests has moved from conventional logging to a holistic approach to natural resources management, increasingly taking into consideration the needs and wishes of the rural people who depend heavily on the forest for their livelihood.

During the preparation of the study, coordination was sought with RNR-RC Bumthang (having the regional mandate for research in the east-central region); RNR-RC Yusipang (having the sectoral mandate for forestry research); DFO Bumthang, Mr. Karma Dukpa (who already had formulated the need for such a study in the past); as well as with the FRDS and the SFES of the FSD.

The fieldwork, which took place during October 1996, was conducted by Tashi (DRO FRDS), Tshering Phuntsho (Ass. DFEO Dzongkhag Forestry Extension Sector), Bangtang and Sherub (FG Zhemgang RO), Ugyen Lhendup (Ass. Lifestock Extension Officer) and Sangay Wangdi (Ass. Agricultural Extension Officer RNR-RC Tintinbi), Yam Bdr. Mongar and Sonam Jamtsho (NRTI trainees attached to RNR-RC Tintinbi). Our sincere thanks go to these people who contributed more than was asked for in their fieldwork and excellent communications with the village people. Without their dedicated job, this study would not have been possible.

Tashi, who was responsible for translating all the various replies into a standard format, did all the data entry in the office. His outstanding work in this contributed greatly to a smoother and better analysis of the data. Thanks are also due to Mr. David Young, who gave a helping hand with the design of the input formats in the computer.

ACRONYMS

BDFC	Bhutan Development Finance Corporation
DFEO	Dzongkhag Forest Extension Officer
FDC	Forest Development Corporation
FMU	Forest Management Unit
FRDS	Forest Resources Development Section
FSD	Forestry Services Division
ha	hectare
hh	household
IPMDP	Integrated Pest Management Development Program
ISDP	Integrated Sustainable Development Project
km	kilometer
m^3	cubic meter
MoA	Ministry of Agriculture
NEC	National Environment Commission
Nu	Ngultrum (Bhutanese Currency; 1 US$ = ca 38 Nu)
RGoB	Royal Government of Bhutan
RNR-RC	Renewable Natural Resources Research Center
RO	Range Office
SFES	Social Forestry and Extension Section
SNV	Netherlands development organization

GLOSSARY

cham	medium size log
dangchung	small pole
dzongkhag	district
gup	elected leader of a gewog (block)
komshing	dry land
mang ap	village elder
shinglep	shingle
sokshing	area for collection of leaf litter
tsamdrog	forest grazing
tsheri	shifting cultivation
tshogpa	committee member