PREFACE

This special issue of INFORMATORE BOTANICO ITALIANO contains a selection of papers presented at the Conference "*Forest Ecosystems: Ecology, Conservation and Sustainable Management*" held in China, in August 15-21, 2000. Conference sessions, with oral and poster presentations, were mixed with post conference excursions and site visits covering representing a wide range of research activities, forest types and management practices. More than 78 participants, from 23 countries, took part in the whole workshop and additional participants of the host country joined in.

The objectives of the Conference were: 1) To analyse how diversity and dynamics of forest communities affect the exchange of carbon and water, and its implications for forest ecosystem productivity; 2) To understand interacting mechanisms between forest ecosystem, environment, society and economy; 3) To define sustainable management of forest ecosystem on stand, landscape and territorial levels. Emphasis was placed on the links between genetic diversity, ecosystem processes and functions, and preventing land degradation and maintaining productive capacity. These links are still poorly developed, but should be strengthened to develop new criteria of multipurpose (production, conservation, ecotourism, amenity, etc.) sustainable management of different forest ecosystem types and of protective areas. This wide scope resulted in contributions from a range of disciplines including ecology, meteorology, remote sensing, physiology, forest management, landscape management, socio-economy, and forest policy. The ecology of forest ecosystems, the preservation and use of natural resources, and the study of the interaction between climate change and plant life, are topics that only recently got the deserved attention. Many of the presentations emphasised the need and potential for applying current interdisciplinary knowledge to sustainable management of our forest resources in current and future climatic conditions. While the lack of knowledge over the precise climate and land-use in the future makes exact predictions impossible, it is important to be able to predict the consequences of defined scenarios and to identify the most sensitive components of managed systems.. To this end, the need for international collaboration through multidisciplinary cooperation networks to analyse the impact of global change on forest ecosystems, its effects on soil degradation, and socio-economic consequences were stressed. Dissemination of the conference results will help national programmes to plan site-related management strategies and adaptive research for both today's rapidly changing environment, and for future conditions.

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The Editors
ZEHUI JIANG ZEHUI, MAURO CENTRITTO, SHOUGONG ZHANG and SHIRONG LIU

Zehui Jiang Zehui
Vice Chair of the Commission on Population, Resources and Environment, Chinese People's Political Consultative Conference National Committee
President of the Chinese Academy of Forestry
Beijing 100091
PR. China.

Mauro Centritto
Istituto di Biologia Agroambientale e Forestale
Consiglio Nazionale delle Ricerche
Via Salaria km 29.300
00016 Monterotondo Scalo (RM)
Italy

Shougong Zhang
Director of Sustainable Forestry Research and Development Center
Vice President of the Chinese Academy of Forestry
Beijing, 100091
P.R. China

Shirong Liu
Institute of Forest Ecology, Environment and Protection
Chinese Academy of Forestry
Beijing, 100091
P.R. China

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Proceedings "International Conference on Forest Ecosystems"

Growth and photosynthesis of cherry saplings in response to moderate shade

M. CENTRITTO, F. PIETRINI, G. SORRENTINO and S. LIU

ABSTRACT - Cherry (*Prunus avium*) saplings (cultivar GiSelA) were grown for two growing seasons under natural sunlight (controls) or moderate shading (up to 30%, depending on the incident light intensity and the hour of the day). Plants were grown in 10 dm³ pots, during the first growing season, and in 15 dm³ pots, during the second growing season, and were fertilised once a week following Ingestad principles in order to supply mineral nutrients at free access rates. Reduced light intensity increased plant component dry mass. Consequently, total dry mass of shaded plants was significantly larger than that of controls at the end of both the growing seasons. The diurnal trend of photosynthesis per unit of leaf area of shaded plants was similar to controls during the hottest summer days in both growing seasons. However, in the second growing seasons, the daily integral of net leaf carbon assimilation was larger in shaded than in control saplings. Thus, it is suggested that the increased growth of shaded plants originates from larger whole-plant photosynthesis. Although transpiration rate in the control was significantly higher than in the shaded condition only in the first growing season, water use efficiency of shaded plants was improved in both growing seasons. Our results suggest that a moderate shading by decreasing the energy load and functioning as a barrier to turbulent diffusion transfer (i.e. thicker boundary layer), can be a useful practice for tempering the environment surrounding plants and, thus, improving growth in hot and dry environments.

Key-words: cherry, growth, photosynthesis, plant dry mass, shading, transpiration, water use efficiency

INTRODUCTION

The global environment is changing with increasing [CO_2] and other so-called greenhouse gases such as methane, chlorofluorocarbons and nitrous oxide (IPCC, 1996). Temperature increase at the earth's surface, driven by rising [CO_2], will lead to the scenario of future higher evaporative demand and drought occurrence. Water shortage is already a major factor limiting plant productivity over large areas of the globe, where it affects growth of both agricultural and forestry species. However, with the future scenario of global change, agriculture and forestry will experience an increased frequency and intensity of drought, critically influencing the patterns of future production. Thus, to encourage sustainable development it is of paramount importance to assess adaptation and mitigation strategies to climate change.

Plant evapotraspiration is driven by the vapor pressure deficit between leaf and air (VPD). This, in turn, depends on air temperature which may be partially controlled by changing the incident light intensity. It is well known that evapotranspiration can be decreased by screen shelters (ALLEN, 1975; LOOMIS, 1983). Reduced incident light intensity may lower air temperature and humidity gradients between leaf and air but may also limit photosynthesis and, consequently, depress plant growth. However, if positive effects of reducing incoming radiation on air and leaf temperatures and VPD above the canopy are larger than negative effects on photosynthesis, growth conditions may be ameliorated and a higher rate of growth may be induced.

The current series of experiments was designed to test whether manipulation of light regimes could improve growth of cherry saplings. Cherry (*Prunus avium*) is an important and valuable agricultural and timber crop throughout Europe. Cherry fruit production is economically important in Southern Europe, where summers are typically hot and dry. Under these conditions, environmental stresses such as high temperatures and drought are frequent and constitute by far the main limitation to plant growth and production. In a previous paper (CENTRITTO *et al.*, 2000), we characterised growth, photosynthesis, water use efficiency (WUE), evapotranspiration, and leaf anatomy of the cherry saplings in response to moderate shading in the first growing season. In this study we report the growth and physiological responses of the cherry saplings after two years of exposure to moderate shading. The saplings were fertilised following the Ingestad approach (INGESTAD, ÅGREN, 1995), to provide a supply of mineral nutrients at free access in order to maintain nutrient uptake proportional to plant growth, ruling out undefined variability in sink strength that might have been caused by water and nutrient deficiencies.

MATERIALS AND METHODS

Cherry clonal saplings (cultivar GiSelA) were grown for two growing seasons under two light regimes. Plants were grown in 10 dm^3 pots, during the first growing season which started on July 25 (day 1), and ended on 23 October (day 90). In the second growing season the saplings were transplanted before budburst into 15 dm^3 pots. The second growing season started on 5 April which is shown, for convenience, consecutively on the figures as day 91. The saplings were potted into standard potting compost (sand:peat:loam mixture 1:5:3), and, to avoid any water and nutrient limitation, were watered every other day to pot water capacity and fertilised once a week with complete nutrient solution, using the stock solutions described by INGESTAD, LUND (1986).

Three-month-old saplings of similar height (10 to 15 cm) and equal number of leaves (5 to 7) were selected and then divided in two groups. Fifty plants were grown under natural sunlight (control) and fifty plants were shaded by a white fiberglass net that reduced incident radiation up to 30%, depending on the incident light intensity and the hour of the day. The white fiberglass net was not extended to the base of the canopy in order not to shade the seedlings in the early morning or in the late afternoon-evening onset, i.e. when the incident radiation was well below saturation.

Six harvests were made to calculate growth rate and six plants were sampled at each harvest. After the baseline harvest, three other harvests were made to determine growth during the first growing season: July 25 (baseline harvest, day 1), August 29 (day 35), September 26 (day 65), and October 23 (day 90), 1997. There were two harvests during the second growing season: on June 24 (day 175), and September 4 (day 247) 1998. Each plant was divided into leaf, stem (including branches), and root and the single parts were oven dried for 48 h at 70 °C to obtain the dry mass. Leaf area was measured using a leaf area meter (LI 3100, LI-COR Inc., Lincoln, NE, USA).

Diurnal trends of photosynthesis (μmol $m^{-2}s^{-1}$) and transpiration (mmol $m^{-2}s^{-1}$) were measured with the gas-exchange open system described by LORETO *et al.* (1994), and were calculated as described by VON CAEMMERER, FARQUHAR (1981). The measurements were made on fully expanded leaves on day 35 (first growing season) and 227 (second growing season), at growth conditions of temperature, RH, incident photosynthetic photon flux density (PPFD), and [CO_2], using a LiCor 6262 (LI-COR, Lincoln, NE, USA) infrared gas analyzer and a small leaf cuvette enclosing a leaf area of 4.9 cm^2. The leaves were illuminated by an optic fiber ring connected to a Schott KL1500 (Schott, Mainz, Germany) light source.

Data were tested using a simple factorial ANOVA (two-way maximum interactions) to determine the main effects of light treatment and time on all dependent variables measured. Where appropriate, the treatment means were compared using Tukey's test.

RESULTS AND DISCUSSION

The objective of this study was to evaluate the growth and physiological responses of cherry plants to a modified microclimate on a field scale caused by a moderate reduction of light intensity. The rationale of our investigation is that a shade net by decreasing the energy load and functioning as a barrier to turbulent diffusion transfer (i.e. thicker boundary layer) would temper the climate of hot and arid environment (i.e. reduced air temperature and increased humidity), resulting effective in decreasing both carbon loss through photorespiration and water loss through evapotranspiration. However, there are conflicting reports in the literature on growth responses of plants to shading (ALLEN, 1975; KAPPEL, FLORE, 1983; LOOMIS, 1983; GIVNISH, 1988; OSMOND, CHOW, 1988; JONES, MCLEOD, 1990; ALLARD *et al.*, 1991; STONEMAN, DELL, 1993; GOTTSCHALK, 1994; WIEBEL *et al.*, 1994; MITCHELL, ARNOTT, 1995; HAMPSON *et al.*, 1996). Some discrepancies may be attributed to differences in the experimental conditions: i.e. heavy shading (up to 9% of full sun) or plant shaded also when the incident radiation was well below saturation. These differences in the experimental conditions may have produced contrasting effect on photo-synthesis, photo-respiration, evapotranspiration, and, in turn on plant growth.

In our study we avoided employing the black or dense nets commonly used for crops and nursery trees. In fact these nets reduce air temperature and, therefore, evapotranspiration, but by heavily cutting light intensity they may also reduce plant growth remarkably. Consequently, we tempered the aerial environment of plants by using a white fiberglass net that reduced incident radiation of about 30% of full sun (i.e. the hottest hours of the day), and to a much lower extent in the early morning or in the late afternoon-evening onset (i.e. when the incident radiation was well below saturation) because the white net was not extended to the base of the canopy. In this conditions, evapotranspiration and photorespiration would be decreased, whereas photosynthesis would not be inhibited by an excessive attenuation of the incoming radiation by the shading net.

Leaf area of shaded plants was significantly (P < 0.05) larger than that of control at the end of the first growing season (day 90), but there were no longer differences during the second growing season (Fig. 1a). In contrast, number of leaves was not affected by shading in both growing seasons (Fig. 1b). The lack of significant differences in leaf area in the second growing season may have been caused by the adverse growth conditions caused by shading during spring between day 91 and day 172, when leaf development occurred. During spring the environmental conditions progressively approach the optimum for growth. Consequently, any reduction in the incoming radiation as well as in air and leaf temperatures brought about by shading has an adverse repercussion on growth.

Leaf dry mass of shaded plants was significantly ($P < 0.05$) larger than that of control at the end of the first growing season (Fig. 2a). Stem dry mass (Fig. 2b), root dry mass (Fig. 2c), and, thus, total plant dry mass (Fig. 2d) were also significantly ($P < 0.05$) increased by shading at the end the first growing season. However, similarly to leaf area, shading significantly reduced light as well as air and leaf temperatures at the beginning of the second growing season (between day 91 and day 172) resulting in an adverse effect on total and component dry mass production.

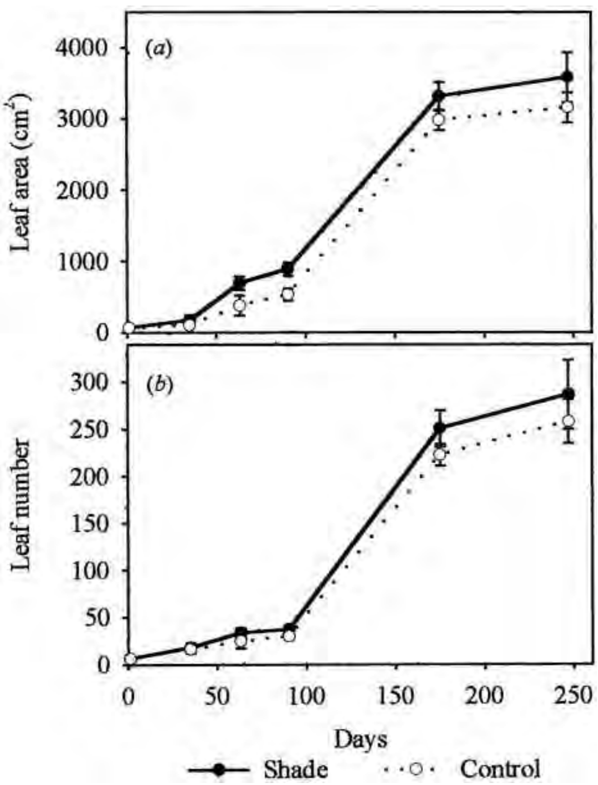

Fig. 1

Leaf area (*a*) and leaf number (*b*) of cherry saplings grown in shaded and in full light conditions in the first and second growing season, shown as day from the beginning of the experiment. Data are means of 6 plants per treatment ± 1 SEM.

Area fogliare (*a*) e numero di foglie (*b*) di piantine di ciliegio cresciute in piena luce o in condizioni di ombreggiamento durante la prima e la seconda stagione di crescita. I dati sono medie di 6 piante per trattamento ± 1 SEM. Days = giorni dall'inizio dell'esperimento.

However, as the growing season proceeded, and the climate became hot and arid, the beneficial effect of shading on plant growth became evident, and with the exception of leaf dry mass, which showed no differences between treatments, significant ($P < 0.05$) differences in total and component dry mass were found at the end of the second growing season (Fig. 2). Total plant dry mass was increased by about 21% in response to shading at the end of the second growing season.

Fig. 3 shows the diurnal trends of gas-exchange of the cherry saplings measured in August both in the first growing season (day 35) and in the second growing season (day 227). The diurnal trends of light intensity, VPD, and leaf temperature of day 35 and day 227 (representative of the summer conditions of the two different years) are shown in Fig. 3a and in Fig. 3b, respectively. On both days 35 and 227, light intensity, air temperature, and VPD in the control were higher than those in the shaded condition. However, light intensity in the shaded condition was still saturating for most part of the day, from 9:00 to 17:00 (preliminary results of CO_2 assimilation rate in relation to PPFD showed that saturation was around 1000 μmol $m^{-2}s^{-1}$). Consequently, the diurnal trends of photosynthesis did not differ significantly among the two treatments with a maximum in the morning (Fig. 3c and 3d). However, on day 227 the daily integral of net leaf carbon assimilation, derived by integrating the values of the diurnal course of photosynthesis, was significant larger in shaded than in control saplings.

Transpiration rate in the control was significantly ($P < 0.05$) higher than in the shaded condition on day 35 (Fig. 3e). However, there were no differences in the diurnal course of transpiration between treatment on day 227 (Fig. 3f). Since the reduction of transpiration by the shaded conditions on day 35 (Fig. 3e) was not coupled to a similar reduction of photosynthesis (Fig. 3c), water use efficiency (WUE) of shaded plants was improved. Moreover, WUE of shaded plants was improved also on day 227 since the daily integral of leaf transpiration was not statistically different in control and shaded conditions (Fig. 3f), whereas the daily integral of net carbon assimilation was increased by shading (Fig. 3d). The improved WUE of the shaded plants may be caused by a lower air temperature and VPD (Fig. 3a and 3b). We suggest that improved WUE is important when plants are not fully established and environmental conditions are harsh. Moreover, the reduced potential evapotranspiration found by CENTRITTO *et al.* (2000) over the first growing season may confirm the above-mentioned finding.

It is noteworthy that the diurnal trends in photosynthesis (Fig. 3c) and transpiration (Fig. 3e) on day 35 were different from those on day 227 (Fig. 3d and Fig. 3f, respectively). Both photosynthesis and transpiration of the cherry saplings were about three-fold larger in the one-year-old saplings than in the two-year-old saplings, regardless of light treatment. Dramatic changes in the leaf gas-exchange character-

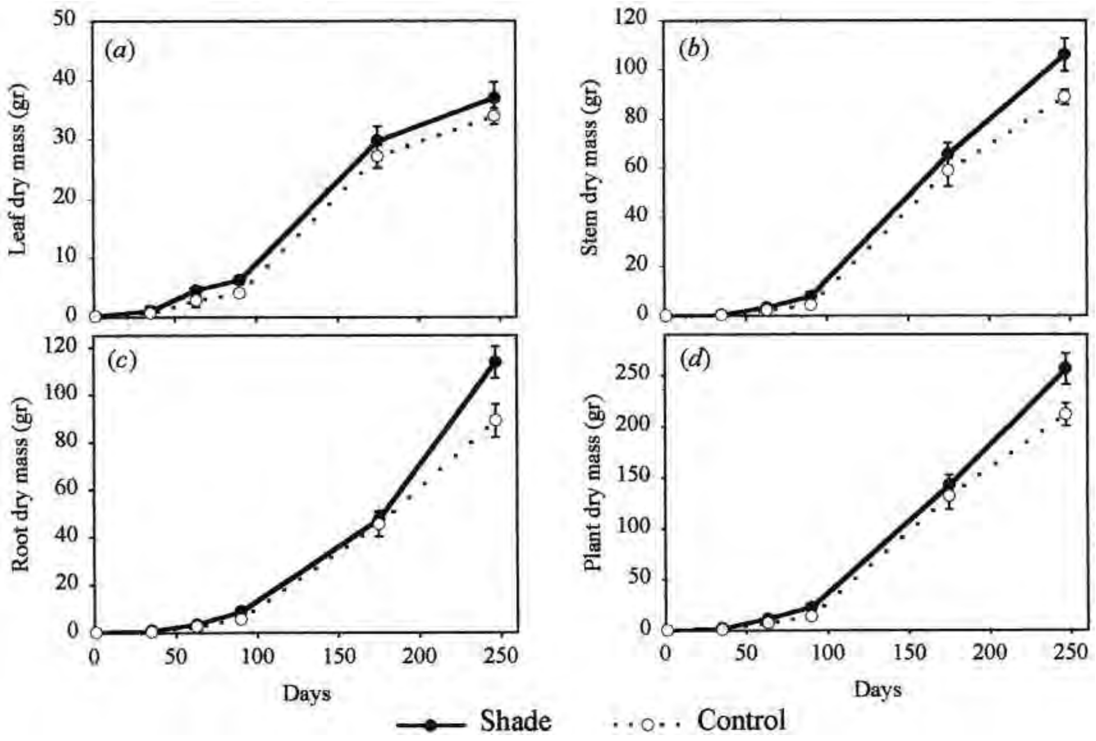

Fig. 2
Mean (*a*) leaf dry mass, (*b*) stem dry mass, (*c*) root dry mass, and (*d*) and total plant dry mass of cherry saplings grown in shaded and in full light conditions in the first and second growing season, shown as days from the beginning of the experiment. Data are means of 6 plants per treatment ± 1 SEM.
Sostanza secca media delle foglie (*a*), degli steli (*b*), delle radici (*c*) e dell'intera pianta (*d*) di piantine di ciliegio cresciute in piena luce o in condizioni di ombreggiamento durante la prima e la seconda stagione di crescita. I dati sono medie di 6 piante per trattamento ± 1 SEM. Days = giorni dall'inizio dell'esperimento.

istics of cherry between the first and second year of age have been reported previously (CENTRITTO *et al.*, 1999b). In a study on cheery seedlings grown for two years in elevated [CO_2], CENTRITTO *et al.* (1999b) showed that A_{MAX}, derived from entire A/C_i curves, was much larger in the first growing season (one-year-old seedlings) than in the second growing season (two-year-old seedlings), regardless of [CO_2] treatments.

As far as we know, no work has previously been done to compare the 'long-term' effects of shading on the plant growth and physiology. Our results clearly show that a moderate reduction of light intensity increased significantly dry mass production of the cherry saplings. This was obtained despite the adverse affect on growth caused by shading the plants at the beginning of the second growing season, when leaf development occurred and the environmental conditions were still below the optimum for growth. We suggest that the apparent contrasting behaviour between diurnal trend of photosynthesis (unaffected by shading) (Fig. 3) and plant growth (increased by shading) (Fig. 2) can be partly attributed to two factors, which determined that the amount of carbon fixed by the whole plant was larger than that which can be inferred from data on instantaneous photosynthesis per unit leaf area: 1) the significantly larger leaf area built by shaded plants in the first growing season (Fig. 1) and 2) the significant increase in the daily integral of net carbon assimilation in response to shading in the second growing season. Moreover, the improved plant growth under shading nets may be also associated with a reduced water consumption, which is another desirable feature in environments characterised water shortage and dry summers. Preliminary results of recent studies on the responses of crops subjected to water stress (CENTRITTO *et al.*, 1999a) or salt stress (DELFINE *et al.*, 2000) to a modified microclimate on a field scale have shown that the yield production was improved by shading with the technique described in our study. The increased yield production resulted from reduced transpiration rates in the shaded crops, which lead in salt-treated tomato plants to decreased leaf and fruit sodium uptake, and, consequently, to a delayed stress onset (DELFINE *et al.*, 2000).

In conclusion, a moderate reduction of light intensity can be a useful practice for increasing the boundary layer thickness and, thus, tempering (i.e. reduced air temperature and increased humidity) the environment surrounding plants in hot and arid areas. This, may promote growth by decreasing both photorespiration and evapotranspiration when plants are

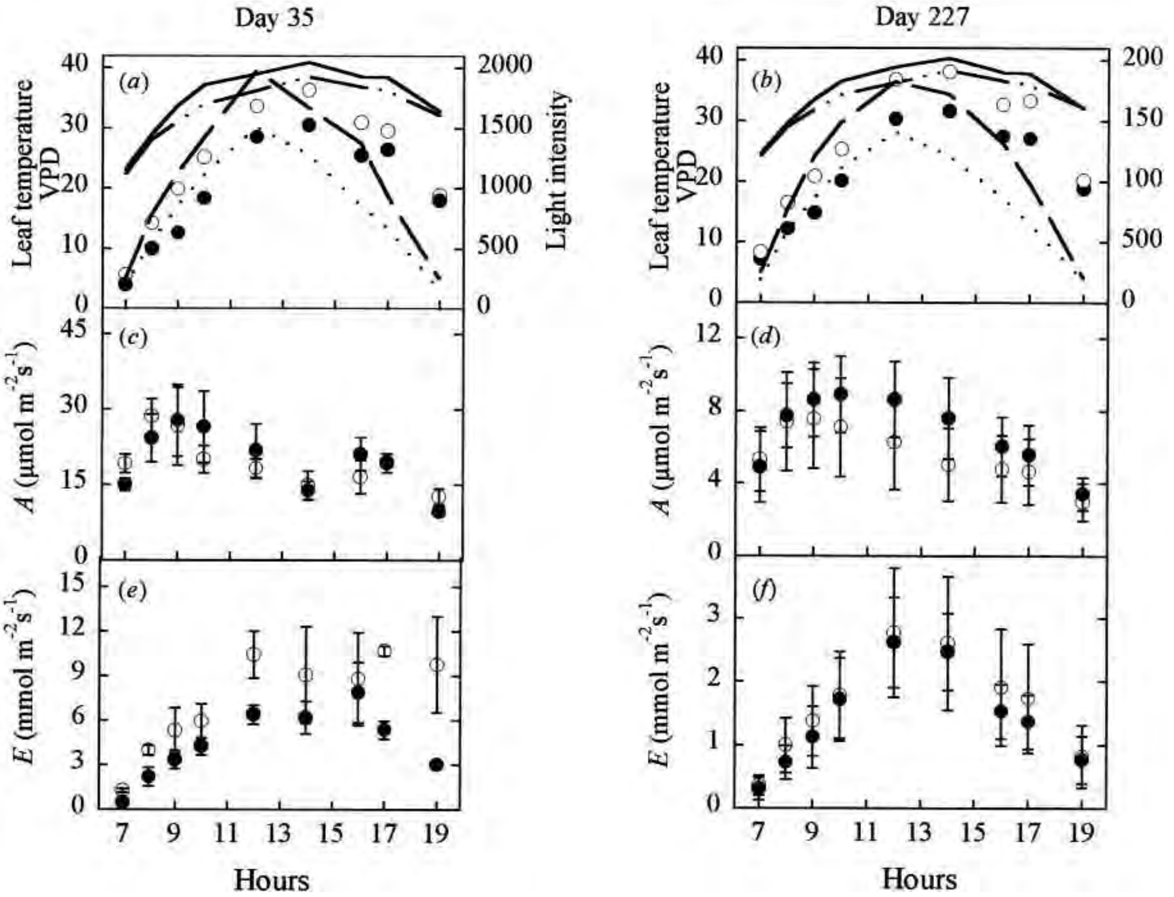

Fig. 3

Diurnal trend of (*a,b*) leaf temperature (—— –··–, °C), leaf to air VPD (O ●, mbar bar^{-1}), light intensity (—— ····, _mol m^{-2}s^{-1}), (*c,d*) photosynthesis (*A*), and (*e,f*) transpiration (*E*) of control (—–,——, O) and shaded (–··–,····, ●) cherry saplings measured on day 35 (*a,c,e*) and day 227 (*b,d,f*). Data are means of 3 to 5 plants per treatment ± 1 SEM.
Andamento diurno della (*a,b*) temperatura fogliare (—— –··–, °C), VPD (O ●, mbar bar^{-1}), intensità luminosa (—— ····, _mol m^{-2}s^{-1}), (*c,d*) fotosintesi (*A*) e (*e,f*) traspirazione (*E*) di piantine di ciliegio cresciute in piena luce (—–,——, O) o in condizioni di ombreggiamento (–··–,····, ●). Le misure sono state effettuate nel giorno 35 (*a,c,e*) e nel giorno 227 (*b,d,f*). I dati sono medie di 3-5 piante per trattamento ± 1 SEM.

exposed to high light intensity and temperatures. Under these conditions, environmental stresses such as drought are frequent and constitute the main limitation to plant growth and production. Considering also the predicted increase in temperature and in frequency of drought associated with [CO_2] build-up in the atmosphere, practices must be implemented in order to reduce evapotranspiration rates and to improve plant growth, particularly in dry-land areas that are prone to desertification processes.

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RIASSUNTO - Piantine di ciliegio (*Prunus avium*), cultivar GiSelA, sono state fatte vegetare per due stagioni di crescita in piena luce (controllo) o in condizioni di moderato ombreggiamento (fino ad un massimo del 30% di riduzione della radiazione solare, in relazione all'intensità della luce incidente e dell'ora del giorno). Le piante, allevate in vasi di 10 dm^3 durante le prima stagione di crescita ed in vasi di 15 dm^3 durante la seconda stagione di crescita, sono state fertilizzate una volta a settimana secondo i principi di Ingestad. Il moderato ombreggiamento delle piante ha determinato un aumento significativo della biomassa prodotta. L'andamento diurno della fotosintesi, misurato nelle giornate più calde dell'estate in entrambe le stagioni di crescita, è risultato simile tra le piante ombreggiate ed il controllo, mentre l'integrale giornaliero dell'assimilazione fogliare netta del carbonio è risultato maggiore nelle piante ombreggiate che nel controllo. L'aumentata crescita delle piante ombreggiate potrebbe essere stata causata quindi da una più elevata fotosintesi complessiva dell'intera pianta, che a sua volta ha indotto una più elevata water use efficiency in entrambe le stagioni di crescita. I nostri risultati suggeriscono che un moderato ombreggiamento, causando una riduzione del carico energetico e funzionando come una barriera alla diffusione turbolenta (strato limite di maggiore spessore), possa essere una pratica utile per temperare l'ambiente circostante le piante e che quindi possa migliorarne la crescita negli ambenti caldi e siccitosi.

AUTHORS

Mauro Centritto, Fabrizio Pietrini, Consiglio Nazionale delle Ricerche - Istituto di Biologia Agroambientale e Forestale, Via Salaria km. 29,300 - 00016 Monterotondo Scalo (Roma) Italy*
Giuseppe Sorrentino, Istituto per i Sistemi Agricoli e Forestali del Mediterraneo, Via Patacca n. 85, 80056 Ercolano (NA), Italy
Shirong Liu, Institute of Forest Ecology and Environment, Chinese Academy of Forestry. Beijing 100091, PR. China

**Corresponding author. Telephone: +39 06 90672731, Fax: +39 06 9064492, E-mail: mauro.centritto@mlib.cnr.it*

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Gas-exchanges by *Eucalyptus* leaves exposed to transient salinity stress

F. LORETO, M. MANNOZZI and P. NASCETTI

ABSTRACT - *Eucalyptus* is one of the tree species of more valuable economic interest and is among the highest isoprene emitting plants. We studied the effect of salinity, an environmental stress to which *Eucalyptus* are often exposed in the Mediterranean area, on physiological gas exchanges, with emphasis on carbon fixation and isoprene emission. Salinity severely but reversibly reduces photosynthesis, stomatal, and mesophyll conductance of *Eucalyptus globulus* leaves, while does not affect significantly isoprene emission. Isoprene emission may even be transiently stimulated when salt stress is relieved and photosynthesis and conductances to CO_2 diffusion partially recover. When photosynthesis and photorespiration are artificially inhibited by gas manipulation, isoprene emission is also stimulated in salt-stressed leaves with respect to controls. Under these conditions the maximum emission occurs at a temperature 5°C higher than in controls, suggesting the activation of alternative pathway of biosynthesis for isoprenoids in leaves exposed to stresses.

Key words: isoprene emission, photosynthesis, salt stress, stomatal and mesophyll conductance

INTRODUCTION

Many tree species emit isoprene, a highly reactive biogenic compound that potentially contribute to the formation of tropospheric ozone (GUENTHER *et al.*, 1991). *Eucalyptus* is one of the highest emitters of isoprene. Therefore, *Eucalyptus* has been chosen as the plant species more suitable for modeling purposes (GUENTHER *et al.*, 1991). Because of their fast growth, *Eucalyptus* trees were planted all around the world for commercial purposes, or for limiting land erosion of de-forested lands. They became often the most common plant species in urban and peri-urban forests, city parks, and green belts. Along the coastal shores of the Mediterranean see, *Eucalyptus* spp. were often planted to break saline wind, and to adsorb saline water and potentially drain soils otherwise unexploitable for agricultural or tourism purposes. Therefore, *Eucalyptus* groves often cope with saline stresses in the Mediterranean environment.

In herbaceous leaves, a moderate salt stress limits CO_2 entry by reducing stomatal and mesophyll conductance, while a severe stress impairs carbon metabolism (DELFINE *et al.*, 1998; DELFINE *et al.*, 1999). These effects are very similar to those observed in water stressed leaves (CORNIC, MASSACCI, 1996). In trees, the effects of salt stress on the physiological properties of the leaves are largely unknown. We investigated the effect of salt on the gas-exchange properties of *Eucalyptus* leaves, focussing in particular on diffusion resistances to CO_2 entry and on isoprene emission. Because of the wide distribution of *Eucalyptus* groves in saline soil, if salt stress affects isoprene emission, it may have a relevant impact on the isoprene presence in the atmosphere over the Mediterranean countries. In particular, we wanted to test if, as in the case of water stress (SHARKEY, LORETO, 1993), recovery from moderate exposure to salt stress could lead to bursts of isoprene emission which are not taken into account by models predicting isoprene emission.

MATERIALS AND METHODS

Three-y-old plants of *Eucalyptus globulus* were grown in 50 L pots filled with sandy and fertilised soil. Plants were irrigated daily to restore evapotranspiration losses and avoid water stress. At the beginning of August the irrigation water was supplemented with 1% (w/v) NaCl for five plants. After three weeks of salt accumulation the NaCl treatment was suspended and the effect of salt dilution by irrigation with salt-free water was followed for one month.

Sodium accumulated in the leaves was extracted from 150 mg of dry leaf mass with the procedure described by DELFINE *et al.* (1999).

Photosynthesis, stomatal and mesophyll conductance were measured using the gas-exchange system described by DELFINE *et al.* (1988). The cuvette was flushed with a one L of synthetic air made by mixing N_2, O_2 and CO_2, and did not contain ozone, isoprenoids and other contaminants. Measurements of gas-exchange and isoprene emission during the salt

stress treatment and the following recovery were done at a leaf temperature of 30 °C and under a light intensity of 1000 µmol $m^{-2}s^{-1}$. A set of measurements was done in CO_2 -free air and low O_2 (20 mmol mol^{-1}) to inhibit both photosynthesis and photorespiration. These measurements were made at temperatures variable between 15 and 45°C. The relative humidity of the air was maintained at 40 to 50% during all measurements. The leaf was maintained at least 30 min in each experimental conditions to reach steady photosynthesis and isoprene emission before measurements.
Isoprene emission was measured by diverting a part of the air exiting the cuvette (40 mL) into a gas-chromatograph (Syntech GC855 series 600, Syntech, Groningen, The Netherlands).
All measurements were made on the last fully expanded leaf of a branch and repeated on five leaves of different plants. Means of the measurements are shown, s.e. is always lower than 15%.

RESULTS

Sodium was more than 8% of the leaf d.w. after three weeks of NaCl feeding (Fig. 1 arrows). This concentration decreased when leaves were re-irrigated with salt-free water but the Na content was still about 4% of the leaf d.w. after a one-month recovery.
Leaf photosynthesis (Fig. 1a) and stomatal and mesophyll conductances (Fig. 1b) were inhibited by Na accumulation but all these parameters substantially recovered after re-irrigation with salt-free water. Isoprene emission, on the contrary, was not severely affected by Na accumulation (Fig. 1a). A slight reduction of the emission was observed during the stress. However, coincident with the maximum recovery of photosynthesis and stomatal conductance, isoprene emission peaked.
When photosynthesis and photorespiration were inhibited by CO_2 and O_2 removal, isoprene emission dropped but the emission of salt-stressed leaves was twice that of controls at 30°C (Fig. 2). The maximum emission of salt-stressed leaves maintained under CO_2 -free and low O_2 air was observed at a temperature (45°C) higher than in controls (40°C).

DISCUSSION

Salt stress significantly affected carbon assimilation but did not reduce to a big extent the emission of isoprene by *Eucalyptus* leaves. DELFINE *et al.* (1998) showed that mesophyll resistance increased during salt stress episodes and was partially eased during recovery from the stress, and suggested that diffusion resistances are solely responsible for photosynthesis limitation under moderate salt stress (DELFINE *et al.*, 1999). As reported by DELFINE *et al.* (1999) we also found that photosynthesis and stomatal conductance almost completely, though transiently, recovered when salt accumulation was reversed (Fig. 1). Thus the inhibition of photosynthesis in salt-stressed *Eucalyptus* leaves might only be attributable to diffusion (stomatal and mesophyll) resistances.

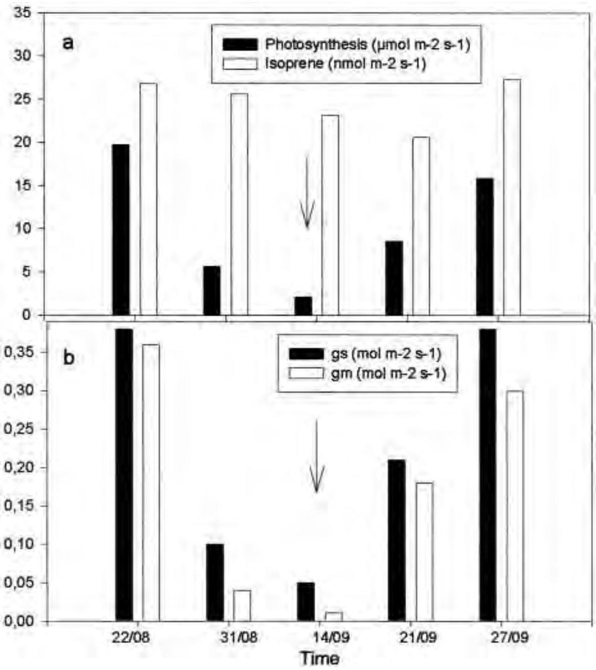

Fig. 1
Photosynthesis and isoprene emission (a) and stomatal (g_s) and mesophyll (g_m) conductance (b) of *Eucalyptus* leaves with increasing (before arrows) and decreasing (after arrows) salt content. The arrows indicate a Na content of a 8.2 ± 1.1% of the leaf d.w.
Fotosintesi ed emissione di isoprene (a) e conducibilità stomatica (g_s) e del mesofillo (g_m) (b) di foglie di *Eucalyptus* esposte a crescenti (prima delle frecce) o decrescenti (dopo le frecce) concentrazioni saline. Le frecce indicano una concentrazioine di sodio pari a 8.2 ± 1.1% del peso secco fogliare.

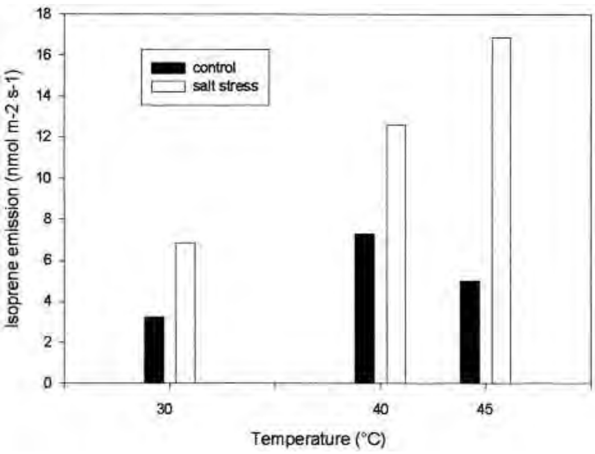

Fig. 2
Emission of isoprene of control and salt-stressed *Eucalyptus* leaves at different temperature and air CO_2-free and with low O_2 concentration (2%).
Emissione di isoprene di foglie di *Eucalyptus* in condizioni di controllo e di stress salino dopo l'esposizione ad aria senza CO_2 e con bassa concentrazione (2%) di O_2.

Isoprene is formed from photosynthetic carbon as indicated by the light - and CO_2 - dependence (LORETO, SHARKEY, 1990), and by the fast labelling by ^{13}C (DELWICHE, SHARKEY, 1993). Despite this, isoprene inhibition was limited and delayed in salt-stressed leaves with respect to photosynthesis inhibition. A similar behavior was found in severely water-stressed kudzu leaves (SHARKEY, LORETO, 1993). Water-stress recovery resulted in an isoprene emission up to five times higher than in controls (SHARKEY, LORETO, 1993). We also found a peak of isoprene emission in *Eucalyptus* leaves two weeks after re-watering with salt-free water. Thus we confirm that isoprene synthesis is resistant to environmental stresses and can even be stimulated by stresses.

It is known that isoprene emission is severely reduced but not totally inhibited when photosynthesis is inhibited by simultaneous removal of CO_2 and O_2 (LORETO, SHARKEY, 1990). This indicates that additional, non-photosynthetic sources of carbon can be used to form isoprene. This effect was even exacerbated in salt-stressed leaves. Therefore alternative biochemical routes of isoprene formation are activated by salt stress and that perhaps a similar effect may be exerted by a range of abiotic and biotic stresses. The +5°C shift of maximal isoprene emission in salt-stressed leaves may indicate the involvement of different enzymatic reactions, perhaps more resistant to the stress.

The sustained investment of carbon into isoprene formation under stress conditions supports the hypothesis that isoprene is involved in resistance mechanisms perhaps protecting membranes (SHARKEY, SINGSAAS, 1995) and should be considered when modeling the emission from stressed vegetation such as in the Mediterranean shoreline.

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RIASSUNTO - L'*Eucalyptus* è tra gli alberi di maggiore interesse economico ed è anche un forte emettitore di isoprene. Abbiamo studiato l'effetto della salinità, uno stress ambientale al quale l'*Eucalyptus* è frequentemente esposto nell'area Mediterranea, sugli scambi gassosi e particolarmente su quelli di CO_2 ed isoprene. Lo stress salino ha severamente, ma in maniera reversibile, ridotto la fotosintesi, la conducibilità stomatica e del mesofillo delle foglie di *Eucalyptus*, mentre non ha avuto alcun effetto significativo sull'emissione di isoprene. L'emissione di isoprene può persino aumentare allorchè lo stress salino viene ridotto e fotosintesi e conducibilità alla diffusione di CO_2 recuperano parzialmente. Quando la fotosintesi e la fotorespirazione sono state artificialmente inibite manipolando la composizione dei gas, l'emissione di isoprene delle piante esposte a stress salino è risultata superiore e ha raggiunto il massimo a temperature di 5°C più elevate rispetto a quella dei controlli non stressati. Ciò suggerisce che in foglie esposte a stress salini si attiva un'alternativa via biosintetica di formazione degli isoprenoidi.

AUTHORS

Francesco Loreto, Michela Mannozzi, Pamela Nascetti, CNR – Istituto di Biologia Agroambientale e Forestale, Via Salaria Km 29.300, 00016 Monterotondo Scalo (RM), Italy*

**Corresponding author*

Growth responses to elevation in *Pinus cembra* in the subalpine zone of Tyrol, Austria

M.H. LI, H. AULITZKY, H. RICHTER, J. NEUNER and CH. KÖRNER

ABSTRACT - The objective of this study is to understand tree growth in afforestations in the starting zones of avalanches. We examined *Pinus cembra* growth across the treeline ecotone. 26 plots were chosen at microhabitats from different altitudes on a S-slope in Schmirn valley, Tyrol, Austria. Between 1700 m and the treeline at 2100 m the average height, diameter and biomass growth decrease with increasing altitude. The correlation between altitude and average height growth was highly significant and could be predicted from non-linear regression analysis. The correlation was not very significant for biomass, and the effect was not significant for diameter. Over the range of altitudes studied, elevation and microhabitat had different influence on tree growth depending on tree age. We conclude that microclimate controls growth during the early life phase of trees, but once trees emerge from the warmer boundary layer, macroclimate dominates growth. In part this may be a consequence of increasing screening of the ground by the developing canopy (reduced soil heat flux), warming in the lower canopy and chilling temperatures at the tree tops may contribute to retarded apical growth at higher elevations.

Key words: alps, biomass, diameter growth, height growth, *Pinus cembra*

INTRODUCTION

Cembran pine (*Pinus cembra*) is a commercially important species of forest in the subalpine zone near the treeline in the Alps, where Forests have been depressed from the natural climatic treeline by land use for several centuries (FROMME, 1957; STERN, 1966; KARL, 1974, 1985; MAYER, OTTO, 1991; LI, 1999). As a consequence avalanche risk is enhanced. The objective of this study is to understand tree growth in afforestations in the starting zones of avalanches (afforestation program by the Section of Torrent and Avalanche Control in Tyrol, between 1968 and 1972). The slowing of tree growth within the treeline ecotone is a well acknowledged phenomenon in the forest literature. Many authors have given a common description of decreasing growth of subalpine trees and forests with rising elevation (OSWALD, 1963; TRANQUILLINI, 1979; KRONFUSS, 1994; KÖRNER, 1998, 1999; BERNOULLI, KÖRNER, 1999; KRONFUSS, HAVRANEK, 1999). The reduction of tree height with increasing elevation was site-specific and varied between 2 and 17 m per 100 m of elevation in the Swiss and Austrian Alps (PAULSEN et al., 2000). Between 1700 and 1900 m in the Sellrain valley (47°13'N, 11°06'E), Tyrol/Austria, annual height growth of *Pinus cembra* decreased with altitude by about 5-6% per 100 m corresponding to the decrease in length of the growing season (KRONFUSS, HAVRANEK, 1999). PAULSEN *et al.* (2000) also found a change in radial growth with time over the last two centuries (1800 – 1996, *Pinus cembra* in the Central Alps). In the first part of the 19th century, annual increments linearly decreased with increasing elevation. After 1940, average tree-ring width with the uppermost 250 m below the outpost treeline was similar, irrespective of the elevation of the tree location (PAULSEN *et al.*, 2000). KAHN (1994) and PENG (2000) have published a summary about the modelling methods of relation between the growth/yield and habitats of forests. We examined three growth parameters on different microhabitats across the treeline ecotone in 1997 (summer), in order to understand the growth responses to elevation and microhabitat in the subalpine zone.

MATERIALS AND METHODS

The afforested area is on a S-slope in Schmirn valley (11°30' E, 47°07' N), Tyrol/Austria, and extends from 1700 to 2100 m a.s.l. The climatic data for this valley (1400 m a.s.l.) is: annual mean temperature 4 - 5°C; mean temperature in July 12 – 14 °C; mean temperature in January -5 to -4 °C; mean annual precipitation 1000 - 1200 mm (of which 25 - 33%

as snow in winter). Cembran pine trees studied are about 32 years old. Soils belong to the podsolic brown, with humus horizons originating from slate developed. The vegetation at the beginning of the afforestation consisted of *Rhododendretum ferruginei, Vaccinieta, Calluneta* etc. (STERN, 1966). 24 plots were chosen in microhabitats from different altitudes (4 from each of the following locations: 1910, 1990 and 2080 m on 35° S-slope, and 1900, 1970 and 2040 on gently sloping benches (< 15°, S-slope) and 2 additional plots at 1950 m (in the lower part of a very steep S-slope with an inclination of about 60°) and at 1940 m (just below this steep slope; Fig. 1).
The number of trees sampled was 24 - 83 per plot.
Height and diameter (breast-height diameter or diameter at the trunk base) of all healthy trees (individuals without clear signs of damage in the past) were measured in 1997 (summer). 3 - 5 average size trees in each plot were chosen for the annual height increment, annual ring width and biomass growth analysis. The ring width (0.001 mm) was measured and recorded with a digital position meter in combination with a microscope (Digitalpositiometer Typ I, L. Kutschenreiter, Vienna). The ring width data was analyzed with Excel 5.0. The roots were excavated with little losses. The lost root fraction was estimated from the diameter at the broken point. All biomass components were weighed after oven-drying at 75°C for 3 days. The data of height growth was analyzed by one-way ANOVA (Analysis of Variance) and Turkey test for the difference between the means of plots (FOWLER *et al.*, 1998).

RESULTS

Cumulative and annual height growth

The difference in mean cumulative height between the six altitudes was significant ($P = 0.0194$), beginning with the age of 16 years.
At slope positions the difference in tree height became statistically highly significant ($P < 0.001$), when trees reached the age of 19 years. On the gently sloping bench, it took two more years (age 21) for the trend to become significant and the significance

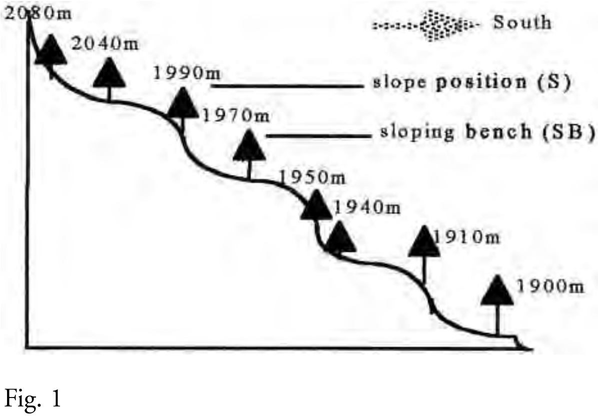

Fig. 1
Plot location.
Sito sperimentale.

was smaller ($P = 0.0037$).
At the age of 31 years, trees mean cumulative height decreased with altitude by 136 cm per 100m on the slope position, and by 108 cm per 100m on the sloping bench. Trees mean annual height growth decreased with altitude by about 35% per 100m on the sloping bench and 43% on the slope position (measured data not shown).
The relationship between cumulative height growth (average height of trees) and altitude is very consistent, but the differentiation by elevation occurred later in favorable microhabitats, i.e. on sloping benches as compared to slope positions (Fig. 2, no data for the plots at 1940 and 1950 m).
The polynomial regression lines (Fig. 2) and equations of mean cumulative height growth of cembran pine show:

On the slope position:
- Plots at 1910 m a.s.l.: $y = 0.9573x^2 - 25.155x + 173.2$; $R^2 = 0.9949$
- Plots at 1990 m a.s.l.: $y = 0.5144x^2 - 15.179x + 121.85$; $R^2 = 0.9798$
- Plots at 2080 m a.s.l.: $y = 0.211x^2 - 4.7301x + 21.672$; $R^2 = 0.9566$

On the gently sloping bench (< 15°):
- Plots at 1900 m a.s.l.: $y = 0.9343x^2 - 24.286x + 164.86$; $R^2 = 0.9922$
- Plots at 1970 m a.s.l.: $y = 0.7925x^2 - 23.198x + 189.08$; $R^2 = 0.9897$
- Plots at 2040 m a.s.l.: $y = 0.4909x^2 - 14.404x + 130.19$; $R^2 = 0.962$

Elevation as well as microhabitat (sloping bench) have not an important influence on the height growth of trees during the young age phase within 16 years (Fig. 2 and 3).
As time goes on, the difference between sloping bench and slope position becomes smaller (Fig. 4), hence microhabitat effects become less important as trees get larger. It is very clear that ØH is larger in young (Ha) vs. older stages (Hb) of tree development. (Fig. 4, ØH indicates the height difference of trees due to position at the upper forest limit).
The exponential regression lines (Fig. 3) and equations of annual height increment of cembran pine show:

On the slope position:
- Plots at 1910 m a.s.l.: $y = 0.7168e^{0.1314x}$; $R^2 = 0.91$
- Plots at 1990 m a.s.l.: $y = 0.1841e^{0.1537x}$; $R^2 = 0.9162$
- Plots at 2080 m a.s.l.: $y = 0.2327e^{0.122x}$; $R^2 = 0.8482$

The consequence of the above is that the elevation becomes more important as trees get older (larger). For instance, the average height of trees at 2040 m (on the sloping bench) was significantly different from that on slope positions at 1990 m and 2080 m at the age of 19 years, but, at the age of 24 years, significant differences occur between 2040 and all other

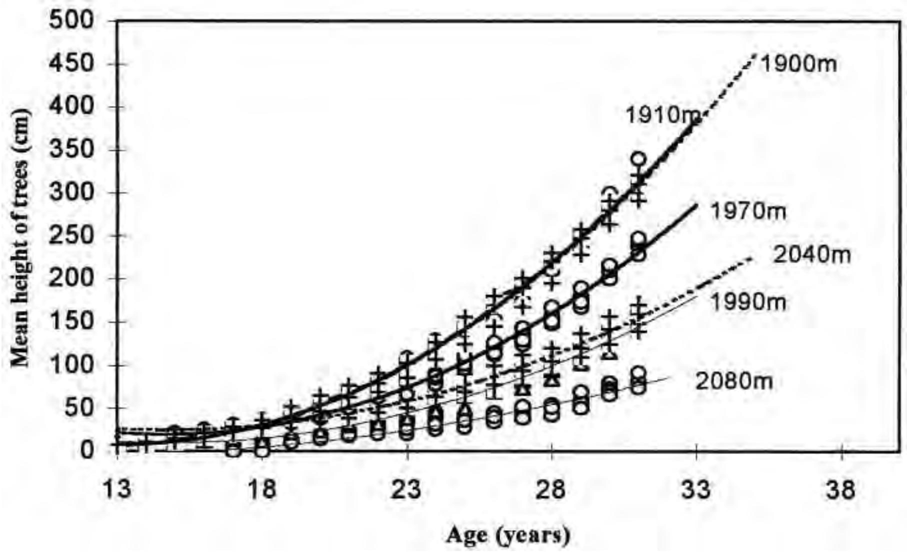

Fig. 2.
Relationships between plant age and height across the 180 m elevation transect below treeline.
Relazioni tra l'età e l'altezza delle piante lungo un transetto di 180 m di altitudine al disotto della treeline.

elevations, except 1990 m (Data not shown).

Diameter growth

In contrast to tree height, there was no regular relationship between radial growth and altitude (Fig. 5). Over the tree ages covered here the radial growth depends more on local environmental conditions at microhabitats (DÄNIKER, 1923; TRANQUILLINI, 1979; LI, 1999). Treerings at 2040 m were as wide as those at 1970 and 1910 m during the last few years. Various site factors influence diameter growth so that its correlation with altitude is less strong than with height growth (TRANQUILLINI, 1979).

Biomass

Total tree biomass decreases drastically with increasing elevation (Tab. 1). At the slope position, total biomass was only 39% (1078g) at 2080 m compared

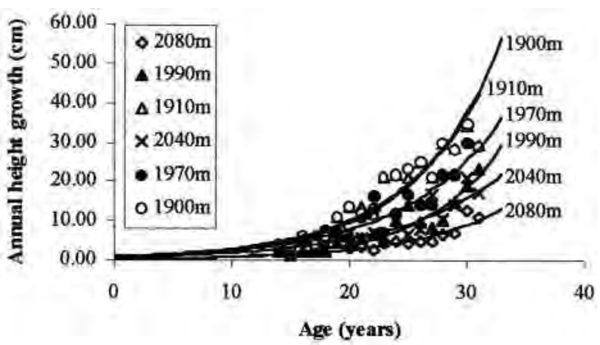

Fig. 3
Annual height growth in relation to elevation and age of trees.
Crescita annua degli alberi in altezza in relazione all'età e all'altitudine.

to 1990 m (2787g), whereas the annual mean growth rate declined from 139g to 43g. Annual biomass growth declined with altitude by 107g per 100 m and the reduction rate was 77%. Similarly on the sloping bench, the total biomass was only 49% (5529g) at 2040 m compared to 1910 m (11327g), whereas the annual mean growth rate declined from 391g to 191g, annual biomass growth declined with altitude by 142g per 100 m and the reduction rate was 37%.
The fraction of needles increases with elevation, in contrast, the stem fraction shows a decreasing trend, and the branch and root fraction do not show any clear trend (Tab. 1, Fig. 6).

DISCUSSION

The reduction of height growth with increasing elevation confirms earlier observations in cembran pine by many authors (OSWALD, 1963; TRANQUILLINI, 1979; KRONFUSS, 1994; KÖRNER, 1998; BERNOULLI, KÖRNER, 1999; KRONFUSS, HAVRANEK, 1999; PAULSEN *et al.*, 2000), and in *Picea abies* as well as in *Larix decidua* (TRANQUILLINI, 1979; LI, 1999), but the decreasing rate is not the same everywhere (KRONFUSS, HAVRANEK, 1999; PAULSEN *et al.*, 2000). Spruce (*Picea abies*) height growth in the Seetal Alps, Austria, proceeds at a mean annual rate of 33 cm in the valley at 700 m but only 8 cm in the zone above timberline at 1900 m (HOLZER, 1967). The annual height growth of spruce seedlings at 1900 m was found only 20% of the maximum value at the optimum altitude of 1250 m in the Wipptal, Austria (TRANQUILLINI, 1979). KRONFUSS, HAVRANEK (1999) showed an annual height growth reduction rate with increasing elevation of only 5-6% per 100 m in the Sellrain valley, Tyrol/Austria. OTT (1978) observed no change in the height of

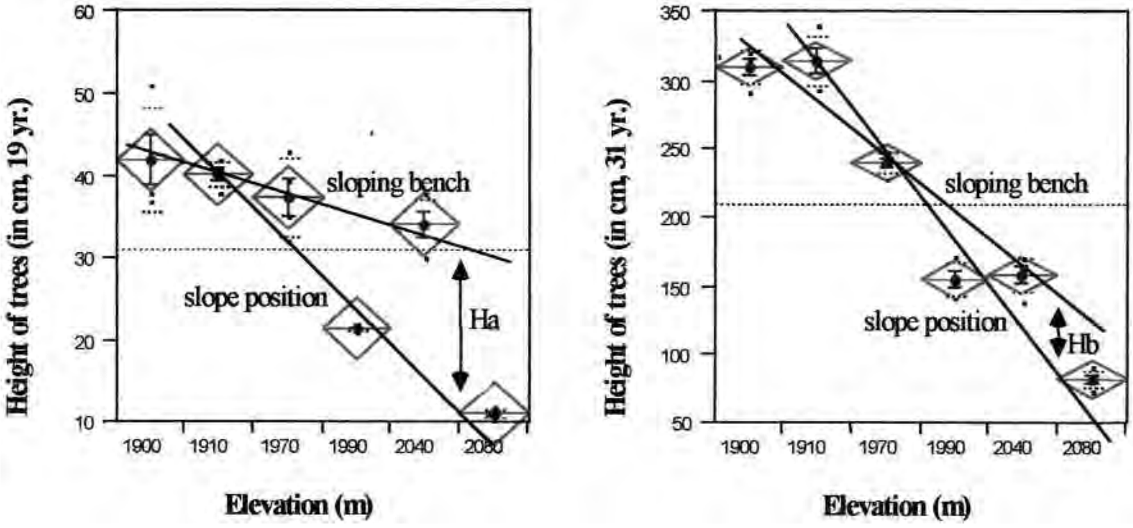

Fig. 4.
Difference in the height of trees among elevations at two ages.
Differenze nell'altezza di alberi di due età diverse in relazione all'altitudine.

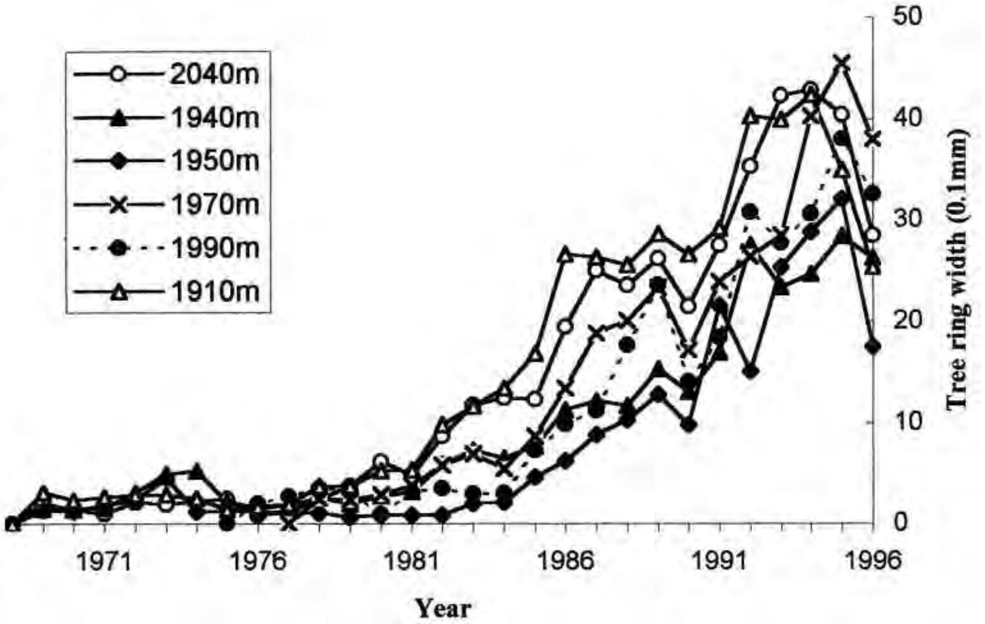

Fig. 5
Mean basal radial growth of the trunk, in relation to elevation and age of trees.
Crescita media della base del tronco degli alberi in relazione all'età e all'altitudine.

mature trees greater than 30 cm diameter in breast-height was detectable for larch (*Larix decidua*) or spruce (at elevations well below tree line up to 1,800 m on a S-slope and up to 1,900 m on a N-slope in the Lötschental, Switzerland). On Mt. Washington in Nevada and in Sellrain valley, tree height also declines rapidly in the upper zone where the forest stand opens out (LAMARCHE *et al.*, 1972; KRONFUSS, HAVRANEK, 1999).

Stem radial growth slightly decreases with altitude just as height growth, but, the trend had not led to a significant relationship between elevation and radial growth. Stem radial growth depends more on local environmental conditions at microhabitats (LI, 1999; see TRANQUILLINI, 1979). This phenomenon has been highlighted also for *Nothofagus solandri* (WARDLE, 1970), *Larix decidua* (LI, 1999) and *Picea abies* (LI, 1999). Also, DÄNIKER (1923) and OSWALD (1969) have shown that diameter increment declines less with altitude than height growth. However, the

TABLE 1
Total dry mass (g) and biomass fractions (% of total tree biomass).
Sostanza secca (g) totale delle piante e delle sue componenti (% della sostanza secca totale).

	Slope position		Sloping bench		
Elevation	2080 m	1990 m	2040 m	1970 m	1900 m
Age (yr.)	25	20	29	22	29
Branches	341 (31,6%)	507 (18,2%)	1235 (22,3%)	1956 (25,5%)	2859 (25,3%)
Needles	346 (32,1%)	663 (23,8%)	1634 (29,6%)	1874 (24.5%)	2788 (24,6%)
Stem	195 (18,1%)	710 (25,5%)	1164 (21,1%)	2092 (27,3%)	3607 (31,8%)
Roots	196 (18,2%)	907 (32,5%)	1496 (27,0%)	1737 (22,7%)	2073 (18,3%)
Below-/above-ground biomass	0,22	0,48	0,37	0,29	0,22
Total tree biomass	1078	2787	5529	7659	11327
Tree density per ha	2400	2800	4200	3700	4000
Total stand biomass (t / ha)	2,59	7,80	23,23	28,34	45,31
Mean growth per tree	43	139	191	348	391

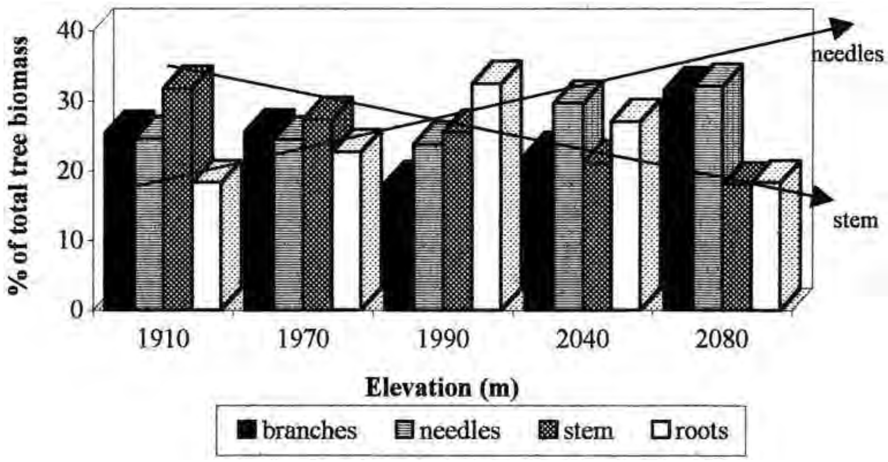

Fig. 6.
Dry matter fraction in *Pinus cembra.*
Frazioni della sostanza secca del *Pinus cembra.*

annual breast-height radial increment of spruce in the Seetal Alps, Austria, was 6 mm at low and moderate altitudes falling rapidly above 1600 m to 3 mm at timberline (TRANQUILLINI, 1979). Similarly, MORK (1960) measured a decline in diameter increment for spruce from 5.0 mm at 140 m to 1.5 mm at 860 m altitude in southern Norway. Radial increment in the larch seedlings dropped from 1.43 mm at 700 m to 0.97 mm at 1300 m and 0.34 mm at 1950 m, but not solely as a result of the shortening growing season at higher altitudes, because the rate of 10-day growth declined with increasing altitude (TRANQUILLINI, UNTERHOLZNER, 1968).
Tree biomass of cembran pine shows a clear reduction with elevation, similar to what had been found by LI (1999) in *Larix decidua* and *Picea abies*. It is remarkable that height growth is the primary cause for biomass reduction. As the annual height growth decreased with altitude by about 35% (on the sloping bench) and 43% (on the slope position) per 100 m, the annual reduction of biomass growth is 37% and 77%, respectively. The marked difference (77% vs. 37%) may result from more stunted morphology of trees in the uppermost area near the treeline. BENECKE (1972) has been found, that seedling dry weight production at 1950 m (timberline) compared to 650 m (valley) was reduced by 42% in *Pinus mugo*, 54% in *Picea abies*, and 73% in *Nothofagus solandri* var. *cliffortioides* in Austria. In the Craigieburn Range, New Zealand, WARDLE (1971) found in seedling establishment trials that dry matter production of *Nothofagus solandri* decreased by

60% from 1100 m to 1600 m altitude. Very surprisingly, (1) the cembran pines at the highest altitude had similar biomass increment to young trees at 200 m lower altitude (OSWALD, 1963); (2) a study from BERNOULLI, KÖRNER (1999) showed no elevational trend in total tree biomass in a similar afforestation (25 years old) in *Pinus cembra, P. uncinata* and *Larix decidua* between 2080 and 2230 m altitude on a NE-slope in Stillberg/Davos, Swiss Alps. In their case, trees also had reduced height at the upper limit of tree growth, but lower branch biomass compensated for the loss in height with respect to biomass.

CONCLUSIONS

Over the range of subalpine altitudes studied here, we have found that elevation effects gradually replace topography (microhabitats) effects as trees get taller. When trees are in their seedling stage, neither microhabitat nor elevation have a strong effect. Once trees exceed a certain height (> 1 m), microhabitat has a significant influence. But, as time goes on and trees are high enough (> 3 m), their canopy is fully coupled to the atmosphere causing growth to decline irrespective of relief. We conclude that microclimate controls growth during the early life phase of trees, but once trees emerge from the warm boundary layer, macroclimate dominates growth. In part this may be a consequence of increasing screening of the ground by the developing canopy (reduced soil heat flux), warming in the lower canopy and chilling temperatures of the tops may contribute to retarded apical growth at higher elevations, in line with a recent theory of tree growth of treeline (KÖRNER, 1998).

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RIASSUNTO - L'obiettivo di questo lavoro è la comprensione della crescita degli alberi nella riforestazione delle aree di formazione delle valanghe. Si è esaminato la crescita del *Pinus cembra* in 26 parcelle esposte a sud, poste a diverse altitudini lungo l'ecotone della treeline della valle di Schmirn, Tirolo, Austria. L'altezza, il diametro e la biomassa media degli alberi cresciuti tra i 1700 m e la treeline (situata a circa 2100 m) decresce all'aumentare dell'altitudine. La correlazione tra l'altitudine e la crescita media in altezza è risultata altamente significativa, mentre le correlazioni tra l'altitudine e la biomassa e l'altitudine ed il diametro delle piante sono risultate non significative.

L'influenza dei microhabitat, presenti lungo il gradiente di altitudini studiato, sulla crescita delle piante è dipesa dall'età delle piante. Noi concludiamo che il microclima controlla la crescita degli alberi durante le loro prime fasi di sviluppo, ma dopo che gli alberi emergono dallo strato limite, che è uno strato relativamente più caldo, le condizioni del macroclima dominano la crescita. Ciò potrebbe essere in parte conseguenza della progressiva schermatura del terreno causata dallo sviluppo progressivo della canopy, che potrebbe determinare un ridotto flusso di calore dal terreno verso l'atmosfera, con conseguente parziale riscaldamento della parte bassa della canopy, mentre quella alta rimane esposta a basse temperature che ne riducono la crescita apicale.

AUTHORS

Mai He Li, Institute for Forest and Mountain Risk Engineering, Vienna University of Agricultural Sciences. Peter Jordan-Stasse 82, A-1190 Vienna, Austria, Current address: Institute of Botany, University of Basel, Schönbeinstrasse 6, CH-4056 Basel, Switzerland. E-mail: maiheli@yahoo.com*
H. Aulitzky, Institute for Forest and Mountain Risk Engineering, Vienna University of Agricultural Sciences.
H. Richter, Institute of Botany, Vienna University of Agricultural Sciences, Gregor Mendel Stasse 33, A-1180 Vienna, Austria
J. Neuner, Section of Torrent and Avalanche Control in Tyrol, Liebenegg-Strasse 11, A-6010 Innsbruck, Austria
Christian Körner, Institute of Botany, University of Basel, Schönbeinstrasse 6, CH-4056 Basel, Switzerland

**Corresponding author*

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Chloroplast markers for phylogeography in European angiosperm tree species: the case studies of *Fraxinus excelsior* L., *Castanea sativa* Mill., and *Populus tremula* L.

S. FINESCHI, D. SALVINI, D. TAURCHINI, M.E. MALVOLTI, M. ANZIDEI and G.G. VENDRAMIN

ABSTRACT - The study of biodiversity in forest tree populations is based on the analysis of genetic markers. Chloroplast DNA (cpDNA) markers have been studied in several European tree species. Here some examples are given on three different species characterised by different life history traits, such as pollination mechanisms, mating system, and mode of seed dispersal. Polymorphism was analysed through the PCR-RFLP and microsatellites chloroplast markers. Chloroplast DNA fragments were amplified *via* PCR using pairs of 'universal primers', which amplify highly variable non-coding cpDNA regions. Amplified fragments were digested by restriction endonucleases and the resulting restriction fragments were separated by gel electrophoresis. For the analysis of the microsatellite sequences, pairs of primers were used for the amplification of specific cpDNA regions, which are known to contain mononucleotide stretches (A/T). The PCR products were then separated according to their sizes by means of polyacrylamide gel electrophoresis using an automatic sequencer. Genetic diversity was analysed at the intraspecific level. Genetic differentiation among populations was expressed by the coefficients G_{ST} and N_{ST} .

Key words: chestnut, chloroplast markers, European ash, European trembling aspen, phylogeography

INTRODUCTION

The study of the geographic distribution of genealogical lineages, what we call phylogeography, allow the interpretation of the present genetic diversity on the basis of historical and evolutionary factors.

Among the historical factors, glacial events of the Quaternary age (the last 2 million years) play in Europe a major role. In the European continent the last ice time lasted about 100'000 years, climate condition started to become warmer about 13'000 BP. According to the biogeographical model proposed by BENNET *et al.* (1991), tree populations survived only in areas characterised by a better climate during cold phases, so called *refugia*, whereas they became extinct in colder zones. At the end of each cold phase, colonisation of the continent started from the glacial *refugia*. Alternating episodes of extinction and recolonisation of tree populations characterised all Quaternary age, including the last interglacial and the last glacial period. BENNETT *et al.* (1991), HEWITT (1996), and TABERLET *et al.* (1998) identified the three Mediterranean peninsulas (Iberian, Italian and Balkan) as the major refugial areas for most temperate tree species. Minor refugial areas, particularly for northern tree species, were located in Eastern European countries. The great mountain chains, Pyrenees, Alps, and Carpathian may have acted as natural barriers for the migration of species and/or of genotypes (HEWITT, 1996).

The role played by these mountain chains for the northward migration has been discussed (TABERLET *et al.*, 1998). The mountain chains acted as barriers to the migration of species such as beech from southern Italy (DEMESURE *et al.*, 1996) and silver fir from Calabria (KONNERT, BERGMAN, 1995), but failed to prevent the migration of black alder (KING, FERRIS, 1998) and, at least for some cpDNA haplotypes, of oak (DUMOLIN-LAPÈGUE *et al.*, 1997a, FINESCHI *et al.*, 2002). Since the Italian peninsula lies in the central part of the Mediterranean basin, it could act as both an origin of migration, and as a meeting point of different migration routes. This hypothesis has been recently discussed for *Castanaea sativa* Mill. (FINESCHI *et al.*, 2000).

During the last decade there have been several studies based on the chloroplast DNA (cpDNA) variation in a wide range of plants, including trees. Organellar DNA markers are very informative to study the postglacial history of many species (SOLTIS *et al.*, 1992; SCHAAL 1998; PETIT 1999). The uniparental nature of inheritance of organelle genomes does not involve recombination, and this makes them particularly suited for phylogenetic and phylogeographic studies. Chloroplasts are maternally inherited in most Angiosperms; for this reason cpDNA based markers are more appropriate than nuclear ones to study seed dispersal events and geographic structure of plants genetic diversity (PETIT *et al.*, 1997).

Studies on organelle DNA markers demonstrated that when seed flow is less efficient than pollen flow, as is the case in many angiosperms, organelle polymorphisms are highly structured as compared to the nuclear ones (PETIT *et al.*, 1993). Phylogeography analysis assumes particular relevance for the conservation of forest genetic resources; the history in the post-glacial period is said to have been the main factor in shaping the actual distribution of the diversity. In this study, chloroplast markers were used to: i) analyse the distribution of haplotypic diversity in Italian and European populations of *Castanea sativa* Mill, *Fraxinus excelsior* L., and *Populus tremula* L.; ii) shed light on the possible migration processes after the last glaciation; iii) understand the role of human impact on the actual distribution of the cytoplasmic diversity.

MATERIALS AND METHODS

24 European ash (*Fraxinus excelsior*) populations have been collected throughout the continent and analysed for both PCR-RFLP and SSR chloroplast markers in the frame of the European project *Measuring molecular differentiation of European deciduous forests for conservation and management* (*Cytofor*, European Union FAIR5 - CT97 – 3795) (VENDRAMIN *et al.*, unpublished data).

38 populations of European chestnut were collected throughout the southern part of the continent and analysed for PCR-RFLP (FINESCHI *et al.*, 2000).

10 natural stands, located in northern, central and southern Italy of *P. tremula* were collected and analysed for both PCR-RFLP and chloroplast mirosatellites (SALVINI *et al.*, 2001).

Universal primers (TABERLET *et al.*, 1991; DEMESURE *et al.*, 1995; DUMOLIN-LAPÈGUE *et al.*, 1997b) were used to amplify *via* PCR non-coding regions of the chloroplast genome; amplified regions were then digested with restriction endonucleases. Restriction fragments were analysed by means of polyacrilamide gel electrophoresis and visualised under UV light.

For the analysis of the microsatellite sequences, pairs of primers were used for the amplification of specific cpDNA regions, which are known to contain mononucleotide stretches (A/T) (WEISING, GARDNER, 1998). The PCR products were then separated according to their sizes by means of polyacrylamide gel electrophoresis using an AlfExpress Pharmacia automatic sequencer.

For each studied species the coefficient of differentiation among populations for unordered alleles G_{ST} (PONS, PETIT, 1995) and ordered alleles N_{ST} (PONS, PETIT, 1996) was calculated.

RESULTS AND DISCUSSION

Fraxinus excelsior L.

Polymorphism detected with both markers is distributed according to the identified four main *refugia*: the Iberian, the Italian, the Alpine, and the east-European ones. Both markers suggested that populations from the British islands appear to have been colonised by a possible Iberian refugium, and that Scandinavian populations might originate from eastern refugial areas. The closely related species *Fraxinus ornus* could be identified with both markers on the basis of distinct chloroplast DNA haplotypes. This is the case of populations from Corsica, Greece and southern Italy.

In both cases, PCR-RFLP and SSR, the values of G_{ST} and N_{ST} were very high: the two parameters are statistically different indicating the presence of a phylogeographic structure in this species (VENDRAMIN *et al.*, unpublished data).

Ash is a anemophylous genus; its winged samaras are mostly wind dispersed (HARLOW *et al.*, 1996). For this reason we could expect lower values of genetic differentiation among populations. The extremely high value of coefficients G_{ST} and N_{ST} detected in this study reveals that genetic diversity is geographic structured because of the origin from different *refugia*, as already suggested by palynological data (BREWER, personal communication).

Castanea sativa Mill.

Eleven different DNA haplotypes were identified by restriction fragment analysis (FINESCHI *et al.*, 2000). The level of population subdivision was relatively low (G_{ST} = 0.43; h_s = 0.38; h_t = 0.68) as compared to other angiosperms studied (review by PETIT, 1999). The level of population subdivision for ordered alleles was significantly higher than the level of subdivision for unordered alleles: N_{ST} = 0.52 (v_s = 0.28; v_t = 0.60).

Chestnut is a species that has been cultivated by man for a long period of time, chestnut propagation material has been transferred over long distances during the last centuries. From the analysis of haplotype distribution we can identify on one hand the human impact on this species in transferring propagation material throughout the continent. On the other hand, we can still identify the possible refugial areas for this species. Results show a possible westward migration from the Turkish *refugium* and a possible eastward migration from the Iberian *refugium*. Our data do not support the hypothesis of an Italian *refugium*; in fact, Italy appears to be a meeting point of different migration routes (FINESCHI *et al.*, 2000). The relatively low level of genetic differentiation among populations is partially unexpected if we think that chestnut produces heavy seeds which are mainly dispersed in the vicinity of the female parent tree, but we should consider that the limited seed dispersal by weight, which is typical of large and heavy seeds (HARLOW *et al.*, 1996), is partially balanced by animals and humans who also contribute to their diffusion.

Populus tremula L.

Six haplotypes were identified by both chloroplast markers. The PCR-RFLP haplotype distribution was similar to that of SSR. For this species only Italian populations were analysed. Values of genetic differentiation measured with the two different markers were very low: G_{ST} = 0.07 (h_s = 0.30; h_t = 0.33) for SSR and G_{ST} = 0.18 (h_s = 0.58; h_t = 0.71) for PCR-RFLP. The level of population subdivision for cytoplasmic genomes for ordered alleles calculated was also very low: R_{ST} = 0.096 (SSR) and N_{ST}= 0.20 (v_s = 0.56; v_t = 0.71) (PCR-RFLP) (SALVINI *et al.*, 2001). European trembling aspen is the most widespread among European poplars. In Mediterranean Europe it is mostly diffused in mountain areas, where it is particularly efficient in colonising marginal, abandoned, and poor soils; suckering habit, typical of all poplars, guarantees agamic propagation. Like other poplar species, European trembling aspen produces anemophilous, imperfect (doiecious plants) flowers in dropping aments appearing before the leaves. The fruit is a capsule containing a number of tufted seeds, which are dispersed by wind (HARLOW *et al.*, 1996).

The low value of genetic differentiation could be mainly explained with the high efficiency of the wind dispersal mechanism of the seeds, typical of pioneer species like poplars. In addition, we should underline that this value may be affected by the limited sampling of this preliminary study (SALVINI *et al.*, 2001). However, similar low value of genetic differentiation has been detected in a study carried out at the European scale (BITTKAU, personal communication).

CONCLUSIONS

Maternally inherited markers revealed high efficiency for phylogeographic studies in angiosperm tree species. The distribution of genetic diversity of European tree species is strongly dependent on the history during last glacial and post glacial period (number and characteristic of *refugia*, pattern of migration, presence of geographic barriers), on their life history traits (mechanisms of seed dispersal, mode of propagation), and on the influence of human activities. For these reasons conservation programs require to realise detailed genetic inventories for each single species. Universal chloroplast markers represent a powerful tool to increase the efficiency of genetic screening.

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RIASSUNTO - Lo studio della biodiversità in popolazioni di alberi forestali si basa sullo studio di marcatori genetici. I marcatori genetici del genoma cloroplastico (cpDNA) sono stati studiati in numerose specie arboree europee. In questo studio vengono discussi i risultati ottenuti su tre specie diverse, caratterizzate da differenti *life history traits* come meccanismi di impollinazione, sistemi di accoppiamento e strategie per la dispersione dei semi. Il polimorfismo viene esaminato attraverso due diversi tipi di marcatori cloroplastici: i frammenti di restrizione (PCR-RFLP) e i microsatelliti (SSR). I frammenti del DNA cloroplastico sono amplificati via PCR utilizzando coppie di 'primer universali' che amplificano regioni non codificanti e altamente variabili del DNA cloroplastico. I frammenti così amplificati sono digeriti con endonucleasi di restrizione e i frammenti che ne risultano sono separati per via elettroforetica. L'analisi di microsatelliti si basa sull'amplificazione via PCR di sequenze note per contenere *stretches* di mononucleotidi (A/T). I prodotti di amplificazione sono separati in base alle loro dimensioni per mezzo di elettroforesi su gel, utilizzando un sequenziatore automatico. La differenziazione tra popolazioni è espressa dai coefficienti G_{ST} e N_{ST}.

AUTHORS

Silvia Fineschi, Daniela Salvini, Daniela Taurchini, Maria Emilia Malvolti, CNR Istituto di Biologia Agroambientale e Forestale, Via Marconi 2, I-05010 Porano (TR), Italy*
Maria Anzidei, Giovanni Giuseppe Vendramin, CNR Istituto di Genetica Vegetale, Sezione di Firenze, Via Atto Vannucci 13, I-50145 Firenze, Italy

**Corresponding author*

Ecology and restoration of sub-alpine ecosystem in western Sichuan, China

S.R. LIU, J.X. WANG and L.W. CHEN

ABSTRACT - The major component of western Sichuan alpine forests is dark coniferous forest, which accounts for 67% of the total volume of Sichuan provincial timber production and is mainly consisted of spruces and firs, such as *Abies faxoniana*, *Picea purpurea* and *Picea asperata*. The dark brown coniferous forest is not only rich in species diversity and timber resource, but also plays an important role in conserving soil and water resources. Canopy rainfall interception ratios of fir stand ranges from 37% to 48%. Thickness of bryophyte and litter ranges from 3 to 10 cm and its biomass was between 14 and 24 t/ha, and the maximum water-holding capacity varies from 4 mm to 7 mm. However, as a result of long-term over-logging on a large scale, the western Sichuan sub-alpine coniferous forest has been greatly reduced and degraded. Species composition and community structure of the existing forests have been modified with the varying degrees, leading to reduction in hydrological functions in terms of water and soil conservation, and consequently, this resulted in frequent flood disaster and water soil erosion in Yangtze river basin. Therefore, ecosystem conservation, restoration and natural regeneration are being highlighted in the sub-alpine region. According to forest type, community structure, and successional stage, five models for restoring disturbed sub-alpine coniferous forest ecosystem were diagnosed and established at Miyaluo alpine region. Applied restoration approaches allow to meet the natural successional path but tend to speed up progressive process by modifying structure in terms of species composition, age-class, diameter-size, and dominate-tree species distribution pattern.

Key words: community structure, hydrology, restoration, sub-alpine

INTRODUCTION

Western Sichuan sub-alpine is an extension of Qinghai-Tibet Plateau towards Southeastern China and largely stretches in the upper valleys of Minjiang River, Yalongjiang River and Jingshajiang River, at the upper reaches of Yangtze River. The topography is characterized with steep mountains and deep valleys. Mountains are usually over 3000 m high, with relative altitude difference ranging from 1000 to 2000 m. Affected by Qing-Tibet plateau's ridge and undulate topography, the thermal pattern and water distribution, microclimate, soil and vegetation vary greatly along vertical elevation. From northwest to southeast, annual average precipitation increases from 600-900 mm to 1500-2200 mm, falling mainly in May through June, with an obvious distinction of rainy season and dry season (YANG, LI., 1990). Such unique geographical features greatly influence forest distribution, composition and structure, and eventually define sub-alpine forest as a water-conserving agent.

The area of western Sichuan sub-alpine is 2.1 million ha, accounting for 39% of the total in Sichuan province. The majority of sub-alpine distributes in an isolated block pattern (LI, 1990). Once alpine is disturbed and damaged, it quite easily succeeds into grassland or shrubs. In addition to ecological vulnerability, sub-alpine plays a significant role in conserving water resource, regulating flood runoff and preventing water and erosion. Therefore, it is critical to ensure sustainable management of sub-alpine ecosystem through effective conservation and ecological restoration. A series of disturbance regime of sub-alpine ecosystem can be easily found and this offers an ideal place to study restoration ecology of western Sichuan sub-alpine.

COMMUNITY CHARACTERISTICS OF SUB-ALPINE

The major component of western Sichuan sub-alpine is dark brown coniferous forest, which accounts for 67% of the total volume of Sichuan provincial timber production and mainly consists of spruce and fir, such as *Abies faxoniana*, *Picea purpurea* and *Picea asperata*. *Abies faxoniana* is well adapted to wet and cold environments, while *Picea asperata* is relatively light favorite and drought-resistant species, and *Picea purpurea* is in between in terms of ecological characters (LI, 1990; YANG, LI, 1990).

***Abies faxoniana* community**

Abies faxoniana forest prevails in western Sichuan alpine region, as it is well adapted to cold and wet microclimate and it usually occurs at a climate climax stage. *Abies faxoniana* pure stand can only be found on shade slopes at an elevation between 2800 m and 3800 m. On north-east or –west aspect, it usually mixes with either *Picea purpurea*, *Picea asperara*, or other broadleaf trees, such as *Betula platyphylla, Betula albo-sinensis*, *Betula utilis*, and *Quercus aquifolioides*. The climate climax community of *Abies faxoniana* only occurs in mixed communities, either with *Picea purpurea* or *Picea asperata*. Pure *Abies faxoniana* forest occurs at over-mature stage with multiple spatial layers and uneven-aged structure. Differentiation of either tree height or tree age tends to be stable at a mature stage.

There are several types of pure *Abies faxoniana* forests in western Sichuan sub-alpine region. Fountain bamboo-fir stand distributes in shade- damp valleys, shrub-fir stand grows on open slopes, moss-fir stand occurs in the middle part of shade-slopes where microclimate is cold and humid. Grass-fir stand occurs on semi-shade slopes, Rhododendron-fir grows on upper slopes with cold-wet environments, while *Quercus aquifolioides* - fir occurs in shady and wet environments.

***Picea purpurea* community**

Picea purpurea is an indigenous species in China. *Picea purpurea* is more light-demanding and drought-tolerant than *Abies faxoniana.* It occurs on slopes regardless of aspects, but largely distributes on northeast or –west aspect and southeast or –west aspects. It occurs in pure stand or it is mixed with *Abies faxoniana*, *Picea purpurea*, and *Quercus aquifolioides*. The mixed *Abies faxoniana* and *Picea purpurea* community is at a climate climax stage. The pure *Picea purpurea* community has multiple layers and uneven-aged structure and it occurs usually at a mature or over-mature status.

There are several stand types of *Picea purpurea* distributing in various different environments. Rhododendron-spruce occurs on north and northeast or north–west aspects, at the elevation between 3800 m and 3900 m. Moss-spruce occurs on semishady and shady slopes at a range of altitude from 3300 m to 3600 m. The moss-spruce is usually mixed with *Abies faxoniana* and *Picea asperata*. Moss layer is thick and luxuriant with dense cover of 90%. Fountain-bamboo spruce grows in deep valleys or on shade slopes of broad-open valleys at an altitude ranging from 3200 m to 3500 m. The fountain-bamboo spruce is productive and has a thicker litter with the moss coverage of 40-90%. It also has a powerful capacity in conserving water and preventing water and soil erosion.

***Picea asperata* community**

Picea asperata is also a native tree species and occurs at an elevation ranging from 2500 m to 3400 m. It is frequently found at over-mature stage of natural successional climax. Mature spruce community is characterized with multiple layers and generations. There are various types of *Picea asperata* communities. Moss-spruce grows largely on shady and semishady slopes at an elevation between 2700 m and 3200 m. It occurs in a pure stand or mixed with *Abies faxoniana* and *Picea purpurea*. The moss layer is thick ranging from 5 cm to 20 cm and dense cover of 80%. Fountain-bamboo spruce grows on north, northeast or northwest aspects of deep valleys at an elevation between 2700 m and 3200 m. It has a dense cover of shrubs and a thick humus layer with a depth of 30 cm, but moss grows poorly.

ECOLOGICAL SUCCESSION OF DARK CONIFEROUS FOREST

Natural regeneration under dark brown coniferous forest canopy is poor or even impossible at clear-cutting sites. Poor natural regeneration was the result of one or more of the following: poor seed germination affected by low soil temperature, low quantity and poor quality of seed production at over-mature stage, deeply dense canopy and thick litter cover (in particular thick moss layer), and quick invasion of shrubs on cutting sites (WANG, XU, 1995). Because dark brown coniferous forests are well adapted to cold and wet environments, its climax community is very stable and therefore other tree species is very hard to take dominant position over natural succession. However, intensive natural and human disturbances can cause larger changes in terms of community structure and ecosystem functions. The following diagrams show their varying successional paths and processes of dark brown coniferous forests after disturbances (Fig. 1).

The successional paths are closely related to flora composition of understorey, because understorey vegetation comes up to be secondary vegetation via succession after disturbance. For instance, rhododendron-fir and fountain bamboo-fir will change into rhododendron-shrub and fountain bamboo-shrub through succession when disturbances exerted. When overstorey trees are clear-cut, moss-fir will be changed into shrub composed largely of hawthorn raspberry in coincidence with quick-disappearance of moss and lichen. Oak-shrub is one of successional stages after oak-fir/spruce forest is burnt or logged repeatedly and it may be reverted back to oak-fir/spruce forest but it is only true where it occurs on cold and wet slopes in deep valleys (LI, 1990).

HYDROLOGICAL FUNCTION OF DARK CONIFEROUS FORESTS

Hydrological functions of western Sichuan dark coniferous forests vary with community types, which largely depend on minor vegetation of understorey (WEN, LIU, 1995). The measurements indicated that the thickness and dry-mass of moss and litter on the forest floor greatly influence water holding capacity. The thicker moss and litter layer, the larger water holding capacity (Tab.1). Fountain bamboo-fir and

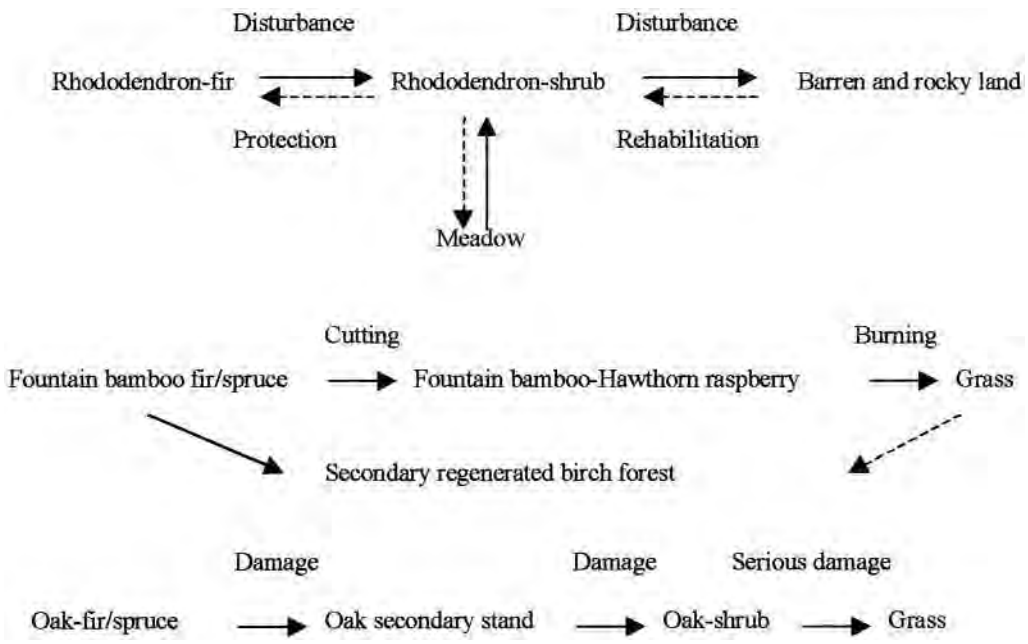

Fig. 1
Successional processes of dark brown coniferous forests after disturbances.
Stadi successionali delle foreste di conifere, formate prevalentemente da abete bianco e da picee, a seguito di perturbazioni.

moss-fir stands have relatively thick mosses and litter layers and large dry-mass, and therefore they have stronger water holding capacity. While Rhododendron-fir and Oak-fir stands have lower water holding capacity due to thin mosses and litter layer. In addition to thickness and dry-mass of litter, water holding capacity of litter is also affected by its decomposition degree, and this further depends on site conditions and litter quality. Growing on southeast or southwest aspect, the litter of fountain bamboo-fir is well decomposed and its decomposed litter accounts for 65% of the total. However, the litter of Oak-fir is poorly decomposed and its decomposed litter only takes up 46% of the total, because it grows on north aspect. Among litter components, moss has the biggest water holding capacity ranging from 450 to 625% relative to its dry-mass, followed by fountain bamboo leaf of 312% oak leaf of 200% and rhododendron leaf of 157%. Therefore, the moss-fir forest has the largest water storage capacity, accounting for 40% of the annual precipitation, followed by the fountain bamboo-fir of 35%. The rhododendron-fir and oak-fir have lower water storage capacity, making up 25% of the annual precipitation.

Soil properties have a significant influence on hydrological function of forest ecosystems. Soil surface runoff is affected by soil water permeability that is dependent on soil physical attributes in terms of soil

TABLE 1
Water holding capacity of moss and litter layer in the four fir stands.
Capacità di ritenzione idrica dello strato di muschio e della lettiera in quattro boschi di abete bianco.

Stand type	Moss-fir	Fountain Bamboo-fir	Oak-fir	Rhododendron-fir
Age	Over 200	Over 140	Over 200	Over 200
Canopy cover	0.7	0.9	0.7	0.7
Mean Height(m)	31	29	12	28
Mean DBH(cm)	43	41	19	45
Altitude(m)	3400	3400	3540	3600-4000
Soil	Peat/brown forest soil	Dark brown forest soil	Dark brown forest soil	Brown forest soil
Litter thickness(cm)	10.2	8.5	3.2	8.0
Dry matter(t/ha)	23.7	21.6	13.9	15.4
Water holding capacity(mm)	7.4	6.1	3.9	4.2
Canopy interception	37.2%	38.2%	48.2%	

buck density and porosity (WEN, LIU, 1995). Dark brown forest soil is commonly found under sub-alpine forests, characterized with deep soil profile and loose structure. Such physical properties are beneficial to soil permeability and water holding capacity. At soil depth of 0-10 cm, the total porosity of fir stands ranges from 90-95%, with the maximum water holding capacity of 90 mm. Down to soil depth of 10-50 cm, the total porosity reduction ranges from 65% to 77%, with the maximum water holding capacity of 70-80 mm. During rainy season, soil moisture can reach a range from 100% to 300%. Soil surface runoff is quite seldom found in dark coniferous forests. A paired watershed experiment indicated that annual average runoff decreased from 487 mm to 313 mm and runoff coefficient decreased from 67% to 33%, as a result of forest cover reduction by logging. This was because that both soil evaporation and vegetation transpiration increased from 30-40% to 60-70% due to increasing air temperature after removal of deep and dense canopy. The increased water loss through evaportranspiration went directly into atmosphere instead of flowing into stream through soil profile. This resulted in runoff reduction accounting for 30 to 40% of total precipitation.

Regardless of stand types, dark brown coniferous forests play an important role in conserving water resource, preventing water and soil erosion, and stabilizing water and nutrient cycling in the upper reaches of Yangtze River by its deep and dense canopy cover, thick moss and litter layers and porous soil structure.

RESTORATION APPROACHES OF DARK BROWN CONIFEROUS FORESTS

Degradation and loss of forests resulting from anthropogenic disturbances in terms of over-logging and shifting cultivation are very likely to have negative effects on hydrological functioning and ecological stability of sub-alpine ecosystems.

There is increasing evidence that reducing forest coverage yields increases in water and soil erosion and flood frequency in Yangtze River. Therefore, it is an increasing concern of restoring degraded sub-alpine ecosystems. Based on forest type, successional stage and disturbance regime, restoration approaches and management scenarios are explored and applied to degraded sub-alpine ecosystem. The approaches are designed to follow natural successional path but tend to speed up progressive process by modifying community structure in terms of species composition, age-class, diameter-size, and dominate-tree distribution pattern (O'HARA, 1998; O'HARA, VALAPPIL, 1999). At the same time, the adopted approaches will be beneficial to improve ecological stability and hydrological functioning of sub-alpine ecosystem. The following five restoration models were diagnosed and established at Miyaluo sub-alpine region based on sustainable forest ecosystem management (LIU, JIANG, 1998) and ecological successional status (ZHANG *et al.*, 1999; ZHANG, CHEN, 2000).

Natural regeneration model

The remaining intact moss-fir stand of 0.5 ha was demarcated for natural regeneration model. This model refers to the virgin *Abies faxoniana* forest, which serves as a management referential model for local climate climax community. The average tree height and DBH of the upperstorey are 27 m and 48cm, respectively, and the density is 370 per ha. Understorey vegetation includes shrubs, herbs and mosses. The shrub and herb covers are 40% and 3%, and their mean heights are 0.9 m and 0.3 m, respectively. Thick mosses densely cover the forest floor, with a depth of 10 cm. This model will be forcibly maintained and protected away from any human disturbances, and let nature do itself via pure natural succession. This model allows to ascertain the role of natural regeneration in driving ecological succession in terms of species composition and diversity, age and diameter structure. Therefore, it can provide valuable information and evidence how to maintain sub-alpine ecosystem health, stability and vitality, and to achieve sustainable management of sub-alpine ecosystem without depressing forest hydrological functioning.

Combination model of natural and artificial regeneration

At an elevation of 3450 m, *Picea purpurea* forest of 1 ha is designed as a combination model of natural and artificial regeneration. The site was clear-cut in 1978, and then spruce regenerated naturally and sparsely with stock density only of 650 per ha. The sparse and poor regeneration could not build up favorable environments for survival and thriving of young spruce saplings and thus natural regeneration process was hampered. In order to improve natural regeneration, supplement planting of spruce seedling was conducted in 1980 according to the density of 900 stock per ha. After 22 years, the mean height and canopy coverage of spruce stand are 6.5 m and 0.65 m, respectively, and its density gets to 1500 stock per ha. It is obvious that *Picea purpurea* forest is progressively succeeding towards its local climate climax community after artificial stimulating natural regeneration.

Removal-cutting model

At the elevation of 3200 m, 1 ha of fountain bamboo-spruce (*Picea asperata*) was established for removal-cutting model. On the clear-cutting site, natural regeneration of spruce seedlings was potentially possible but it was affected by flourishing fountain bamboo. Fountain bamboo spread very quickly on clear-cutting sites and its height and density were 2 m and 18 stock per square meter. For the sake of enhancing natural regeneration and growth of spruce seedlings, removal cutting of fountain bamboo was made during the initial period of 3 or 5 years. After removal cutting, both survival rate and growth rate of naturally regenerated spruce seedlings were greatly improved.

Reforestation with subsequent broadleaf-tree introduction model

At the elevation of 3000 m, 3 ha of *Picea asperata* stand were defined for reforestation and broadleaf-tree introduction model. Spruce seedlings were planted on clear-cutting site in 1978. The mean height and DBH of spruce trees were 11 m and 16.5 cm, respectively, when measured in 1999. The stock density was 1600 per ha and canopy coverage was 0.95. Because *Picea asperata* is a light-demanding and drought-tolerant species, it cannot grow well when canopy overlays and intraspecific competition intensifies with increasing tree volume size. Thus, light thinning was carried out based on diameter-class and spatial distribution pattern in order to reduce competition and to accelerate tree growth and successional progress. Spruce growth in terms of height and diameter was increased by 10-20% after light thinning. At the same time, the light thinning also provided favorable conditions for growth and development of the understorey vegetation including broad-leaf saplings, shrubs and herbs.

In addition to random light thinning, an alternative way was to open up areas within pure spruce stands by removing spruce trees in strips of 3 m or 5 m wide. Such open strips will provide available space for natural regeneration and development of angiosperm species, especially natural broad-leaved trees. The strip cutting will also contribute to formation of semi-natural mixed spruce and broadleaf forest.

Conifer introduction model

At the elevation of 3000 m, 1.5 ha of naturally regenerated secondary broadleaf forest consisting mainly of *Betula albo sinensis*, *Betula platyphylla,* and several maple tree species was laid out for conifer introduction model. This stand came originally from natural regeneration after virgin dark brown coniferous forest was clear-cut 15 years ago. The overstorey tree density was 2800 per ha and understorey cover was 65% when measured in 1999, indicating that forest structure and environments have basically established. However, natural regeneration of conifers was constrained as a result of dense and thick fountain bamboo bush. In order to speed up ecological succession, it is necessary to plant conifers in an open space after strip-cutting with width of 2 m or block light thinning of 1.0 m x 1.0 m. Broadleaf trees and shrubs were removed and instead spruce seedlings (*Picea asperata*) were planted. This approach will also lead to formation of mixed broadleaf and conifer forest.

CONCLUSIONS

In western Sichuan sub-alpine region, complex topography and landforms generate varying site conditions and ecological environments along vertical and horizontal dimensions. This results in abundant diversity in terms of community types and forest fauna and flora. Dark coniferous forest is a major component of western Sichuan sub-alpine and it is also a local climate climax community with multiple spatial layers and uneven-aged structure. Its natural regeneration prevails in a continuous development and multiple generation patterns. The dark coniferous forest plays an important role in conserving water resource and preventing water and soil erosion through deep and dense canopy cover and thick litter, and porous soil. Situated in steep mountains, deep valleys, and head of Yangtze River, western Sichuan sub-alpine should be managed sustainably as water conservation forest, rather than timber forest.

Due to over-logging on a large scale, the sub-alpine has been greatly degraded in terms of ecological functions and community structure. Restoring degraded dark coniferous forest ecosystems is highly concerned and appropriate approaches should be explored on a basis of the following management objectives: to maximize hydrological functioning of forest ecosystems and to speed up natural succession towards local climate climax community with uneven-aged and multiple spatial structure. The five restoration models at Miyaluo alpine region have demonstrated that restored forests are going through their own natural tracks of progressing development towards local climate climax communities.

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RIASSUNTO – Le foreste alpine occidentali del Sichuan, sono formate prevalentemente da abete bianco e da picee, come ad esempio *Abies faxoniana*, *Picea purpurea* e *Picea asperata*, e costituiscono circa il 67% della produzione di legno della provincia di Sichuan. Queste foreste di conifere non sono solo una ricchezza in termini di biodiversità e di risorsa legno, ma giocano un ruolo essenziale nella conservazione del suolo e delle risorse idriche. La quantità di pioggia intercettata dai boschi di abete bianco varia tra il 37 ed il 48%. Lo spessore dello strato di briofite e della lettiera varia tra i 3 ed i 10 cm, la sua biomassa è di circa 14-24 t/ha, mentre la sua massima capacità di ritenzione idrica varia tra i 4 ed i 7 mm. A causa però dei forti ed estesi tagli effettuati da lungo tempo, le foreste subalpine occidentali di conifere del Sichuan si sono fortemente ridotte e degradate. Sia la composizione che la struttura delle rimanenti foreste è stata modificata e ciò ha comportato una riduzione delle sue funzioni idrologiche in termini di conservazione del suolo e dell'acqua, con conseguenti forti erosioni del suolo e frequenti disastrose alluvioni nel bacino idrico dello Yangtze. A seguito di ciò le problematiche della conservazione, recupero e rigenerazione naturale degli ecosistemi sono state messe in luce nella regione subalpina del Sichuan e cinque modelli di recupero degli ecosistemi di foreste di conifere subalpine, in funzione del tipo di foresta, struttura della comunità e stadi successionali, sono stati identificati ed applicati nella regione alpina di Miyaluo. Questi approcci applicativi permettono il naturale susseguirsi degli stadi successionali, ma tendono a rendere più rapida la progressione dei processi, modificandone la struttura in termini di composizione delle specie, classi d'età, grandezza e modello di distribuzione delle specie di alberi dominanti.

AUTHORS

Shirong Liu, Research Institute of Forest Ecology, Environment and Protection, Chinese Academy of Forestry, Beijing 100091, PR. China

Jinxi Wang, Linwu Chen, Ecological Research Institute, Sichuan Academy of Forestry, Chengdu 610081, PR. China

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Distribution characteristic and succession law of alpine forest in western Sichuan

C.H. XIANG and Y.P. YANG

ABSTRACT - The distribution characteristics and succession laws of forests in forest and meadow zone and forest zone of high mountains and canyons are expounded and the relationships of forest succession with vertical gradient and habitat gradient are discussed in this paper. Moreover, the forest succession features of inlay structure and fluctuation drift are proposed and the proposals for use of succession laws in practice are also put forward.

Key words: alpine forest, distribution characteristic, succession law, western Sichuan

INTRODUCTION

The alpine forest region in western Sichuan is situated at the southeast edge of the Qinghai-Xizang (Tibet) Plateau, in the upper reaches of the Changjiang River and on the first terrace of China's general topography classification (LI *et al.*, 1990; YANG, 1993). With high mountains, steep slopes, complex landform and evident vertical changes, forests in this region play an even more significant role in water and soil conservation. Forests are composed of spruces (*Picea*), firs (*Abies)* and birches (*Betula*), etc. (YANG *et al.*, 1956). These forests are of natural origin with crown density of 0.6-0.8, tree height of 30-40 m, breast-height diameter of 40-60 cm and age of 150-300 years. Most of them are multi-storied and uneven aged forests. Under the influence of slope, aspect, elevation, moisture and heat, the alpine forest region has different forest types: fountain bamboo, fir and spruce forest, moss, fir and spruce forest, bush, fir and spruce forest, *Rhododendron* and fir forest, grass, fir and spruce forest, etc. The habitat conditions, productivity, regeneration, succession laws and management measures of these forest types are distinctly different.

DISTRIBUTION CHARACTERISTICS AND SUCCESSION LAWS OF FORESTS IN FOREST AND MEADOW ZONE

Forest and meadow zone is situated in northwestern Sichuan, near Tibet and Qinghai in the west and north, against plateau thicket and meadow grassland in the northwest , nearby and northeast, forest zone of high mountains and canyons in the east and southeast.

Forests are mainly distributed on shaded slopes of narrow valley and plateau with discontinuous patches and stripes. Thicket and meadow are mainly distributed on sunny slopes. The distribution of forest, thicket and meadow in western Sichuan is interlaced. The landscape of forest and meadow in western Sichuan seems similar to forest steppe in northwestern China, but the meadow vegetation in western Sichuan is mesophytic (LI *et al.*, 1990). Forest and meadow zone can not be considered as forest steppe. There is interlaced distribution of forest and meadow in vegetation vertical zonal pattern , but it is influenced by altitude, meadow zone is narrow.

Arbor species are *Picea, Abies, Sabina* and *Larix*. Shrub species are not rich, but they are hardy plant species, such as *Lonicera*, *Rhododendron* and *Salix*. The meadow plant species are rich, such as *Kobresia*, *Festuca*, *Spenceria* and *Polygonum*.

Picea balfouriana forest is major, *Picea purpurea* forest is minor. But they form the typical forest types in interlaced zone of forest and meadow. *Abies faxoniana* forest treychess on the southeast margin of this zone. *Abies squamat* forest distributes on the southwest margin of this zone. But *Abies* forests in this zone are not main. The other forest types, such as *Sabina* forest, distribute a little in this zone.

The special climate condition and altitude decide distribution of dark coniferous forest and plateau thicket and meadow in this zone. Fir forests distribute over the middle and lower parts on shaded slope in deep valleys, but the inversion distribution of spruces and firs often appears in this zone. The

boundary line is at 3500 m above sea level (ASL), spruces appear at more than 3500 m ASL, firs appear at less than 3500 m ASL (YANG *et al.*, 1956).
The natural regeneration in cutting blank is poor in forest and meadow zone, area of meadow and thicket will be enlarged. But the natural regeneration on forest fringes or in forest glade is good. For example, the natural regeneration in *Picea balfouriana* cutting blank with crown density of less than 0.5, herb coverage of 30% and sparse shrubs is good, the process of natural regeneration is continuous, the clumps of young trees form uneven aged forest.
After *Picea balfouriana* forest had met with destruction in forest and meadow zone, *Sabina* rapidly grew in felling blank. Due to forming young stand of *Sabina*, the environment condition in felling blank became better, *Picea balfouriana* would grow, *Picea balfouriana* and *Sabina* gradually formed mixed forest, young trees of *Picea balfouriana* were main in mixed forest. With *Picea balfouriana* rapidly growing, *Sabina* under forest canopy would be replaced by *Picea balfouriana*. The mixed forest of *Picea balfouriana* and *Sabina* was a transitional forest type.
Due to the bad climate condition in forest and meadow zone, if forests suffered serious destruction (intensive burning or large scale clear-cutting), they were easy to be replaced by meadow.

DISTRIBUTION CHARACTERISTICS AND SUCCESSION LAWS OF FORESTS IN FOREST ZONE OF HIGH MOUNTAINS AND CANYONS

The dark coniferous forest zone of high mountains and canyons is situated in western Sichuan, north of Hengduan Mountains (YANG, 1990). The parallel mountains and canyons form landform features of this zone. This zone stretches in the south of Aba and Ganzi autonomous Prefectures, against the boundary of Xuebaoding, Balangshan and Jiudingshan mountains in the east, near dry evergreen pine and oak forest districts on western margin of Sichuan Basin in the south, against Jinsha river in the west, nearby plateau spruce and Juniper forest districts in the north.
The main tree species are *Picea* and *Abies* in this zone, the main tree species of *Abies* are *Abies faxoniana*, *A. sauamata* and *A. georgei*, and the main tree species of *Picea* are *Picea balfouriana*, *P. purpurea*, *P. Likiangensis* and *P. asperata.* The forest area of the main tree species of *Picea* and *Abies* makes up 80-90% of the total area of forest zone with high mountains and canyons. The other tree species are a few, such as larch, birch, Chinese hemlock, and Juniper.
Picea and *Abies* have 20 species in this zone, they form more than 90 forest types. In a certain district, at the same altitude, the forest types and the main tree species are different. The complexity of forest types has close affinity with the complexity of the natural and geographical conditions in this zone.
Abies pure forests or *Abies* mixed forests occupy a dominant position with the distribution center of Miyaluo, Dajin, XiaoJin and Maerkang. From wide plane distribution, *Picea* forest districts distribute between *Abies* forest districts and coniferous and broad-leaved mixed forest districts. The inversion distribution of spruces and firs appears on the margin of this zone.
Abies forests mainly distribute in the middle and upper reaches of rivers and their branches, narrow valleys and on shaded slopes and above an elevation of 3000 m, *Picea* forests mainly distribute in wide valleys and on half shaded and half sunny slopes (YANG, 1993). The secondary thicket or *Quercus* mainly distribute on sunny slopes.
The natural regeneration is poor under Primitive spruce and fir forest canopy, there are tens of thousands of regenerated saplings under their forest canopy in the first year, but after the first year, there are only few regenerated saplings (YANG *et al.*, 1956). The factors of high crown density, low temperature, little light, high humidity, thick litter and poor quality and little quantity of tree seed bring about the above result. But the natural regeneration in the spruce and fire forest glade is good, forms many young trees of different ages, this shows that this natural regeneration of spruce and fir forest glade is continuous and has staged features.
After *Picea* and *Abies* forests are destroyed, they are replaced by *Betula utilis* and *B. albo-siemsis*. After *Abies, Pinus tabulaeformis* or *P. densata* forests are destroyed, they are replaced by *Betula platyphylla* and *Populus davidiana*. If these forests at more than 3600 m suffered serious destruction, they would be replaced by secondary thicket or meadow.
The dark coniferous forests in high mountains and canyons are climax communities with good stability and are difficult to be replaced by other trees in a short time, but human disturbance leads to diverse succession features.
From *Rohododendron* thicket to fountain bamboo thicket, *Larix potaninii* forest to *Acer* and *Betula* mixed forest, and diverse mixed forests in late succession stage show vertical gradient law. From the distribution of *Abies faxohiana* in Sichuan, 3500 m ASL is boundary line (YANG, 1990). At more than 3500 m, the succession main tree species are winter hardy resistance *Larix Pataninii* and *Sabina saltuaria*, at less than 3500 m, are thermophil *Acer* and *Betula*. Morewhile, *Sabina saltuaria* forest and *Quercus* forest grow on sunny slopes (LI *et al.*, 1990).
Secondary types will be formed by plant synusia under primary forests after diverse forest types suffer destruction. For example, *Rhododendron* and fountain bamboo thickets in upper and lower parts of mountain are primary succession stage. But moss will disappear after tree stratum in moss and fir forest is destroyed, the intolerant plant *Rubus* under primary forest rapidly grow and form concentrated thickets. Due to burn or cutting many times , the bush and fir forest is replaced by *Quercus* thicket, *Quercus* thicket is stable. But only in shaded and wet valleys, *Quercus* thicket will grow high forest. The good environment conditions are advantageous to

growth of fir seedlings.

According to former researches, in felling blank, *Rubus* will rapidly grow in 1-2 years, form concentrated thicket in 3-6 years, decline in 7-9 years, be replaced by *Populus davidiana*, *Acer* and *Betula* in 10-20 years. The above statement succession process will be completed by natural succession potentiality. If *Rubus* thickets are cut from their roots, they rapidly grow, the measures are not advantageous to regeneration. Before or after rain season, if the central section of *Rubus* is cut, quantity of *Rubus* will gradually decline. The measures can promote regeneration (YANG, 1972).

The forest succession is evidently influenced by the changes of habitat gradient. The results of regeneration are different on diverse aspect. For example, in dry and cold areas and under *Abies squamata* forest, the regenerated seedlings on shaded slope are 2.5 times more than that on sunny slope, but under *Picea purpurea* forest, there are 2500-3800 seedlings per hectare on half sunny slope, 600-800 seedlings per hectare on shaded slope. The gentle slope is advantageous to natural regeneration. For example, under fir forest, there are 34900 seedlings per hectare on slopes of 5-10°C but only 14100 seedlings per hectare on slopes of 31-45°C. The results of natural regeneration are also different at diverse elevations. Fox example, under fir forest, there are 15557 seedlings per hectare at 3600-3700 m ASL, but only 5900 seedlings per hectare at 3900-4000 m ASL.

There is mutual replacement relationship between spruces and firs especially in the forest zone with high mountains and canyons, this relationship appears in the dark coniferous forests, the fir and spruce mixed forest is formed. In this mixed forest, the dark and damp conditions are advantageous to growth of fir seedlings. The fir seedlings are dominant under forest canopy. After the oldest trees die off, forest glade will appear, the fir seedlings rapidly grow into young trees, the young trees of fir continue to grow and get into the main storey . In the meantime, due to appearing forest glade, the good environment conditions are advantageous to growth of spruce seedlings and young trees. It seems possible that the young trees of spruce will continue to grow and get into main forest storey. So in the spruce and fir mixed forest, fir and spruce maintain fluctuation changes throughout, and form fir clump or spruce clump. From plane distribution, fir and spruce clumps form inlay structure. Fox example, in *Abies faxoniana* and *Picea purpurea* mixed forest, *Abies faxomiona* and *Picea purpurea* clumps form inlay distribution. For another examples, in pure fir forests, there is inlay structure of different age class fir clumps, regeneration and succession are continuous. Fluctuation drift is called the expanding regeneration of forest fringe. The expanding regeneration can occur in all kinds of blanks around forest fringe. The distance of expanding regeneration is often influenced by topography, vegetation and wind direction. Fox example, according to former investigation, in the burn blank of 30 years at 4120 m ALS in Beiyu forestry bureaus, natural regeneration of *Picea balfouriana* occurred within 150 m distance from forest fringe, there were 18000 seedlings per hectare within 50 m distance, 1000-2500 seedlings per hectare within 50-150 m distance, but there were not seedlings beyond 150 m distance. The expanding regeneration on forest fringe formed inevident uneven aged forest, the difference of tree age was age class, the difference of diameter class was little. For another example, from former report, the distance of expanding regeneration from *Picea likiangensis* seed disseminated from forest fringe was 115 m, the natural regeneration was good within the distance of 35-65 m, there were 5500 seedlings of spruce per hectare within the distance of 65 m from forest fringe, there were 2555 seedlings of spruce per hectare within the distance of 65-100 m from forest fringe. The distribution of seedlings was even, they grew well. So forests could be restored by expanding regeneration in all Kinds of blanks on forest fringes.

USE OF FOREST SUCCESSION LAWS IN PRACTICE

Care should be taken to simulate natural community succession laws, to choose native tree species as main, to match species with the site and to create multi-storied structure forest types. Micro-habitat conditions should be created for afforestation in forest and meadow zone or in higher altitude areas.

Closing the land for reforestation is important and economic measures of restoration and rehabilitation vegetation. Adhering to laws of forest succession, succession stages and obstruction factors should be considered. The combining measures of closing the land, cultural operations, filling-up and stand improvement should be taken to speed up restoration of forest vegetation.

According to forest management target, closing the land, filling broad-leaved trees, cultural operations, planting grass and shrub should be used in improvement of even-aged, coniferous and pure forests, low-benefit forests and secondary forests. These measures can promote tree growth and increase the forest function of protection.

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RIASSUNTO - Questo lavoro illustra le relazioni tra le successioni forestali ed i gradienti verticali dei diversi habitat. Inoltre si discute le caratteristiche delle distribuzioni forestali e delle leggi che regolano le successioni nelle aree prative e forestali di alta montagna e dei canyon. Infine, si propone la possibilità di mettere in pratica le leggi delle successioni.

AUTHORS

C.H. Xiang, Y.P. Yang, Sichuan Research Institute Forestry, Chengdu, 610081, China

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Agroforestry for sustainable development: a case study in north Lakhimpur district of Assam (India)

B. SINGH, K.K. SOOD, D. BORA, H. PRASAD and P. RETHY

ABSTRACT - Agroforestry as an integral approach to land use had existed in Assam as traditional farming systems since time immemorial. Agroforestry is widespread in Assam which is evinced by the presence of trees on the farm boundaries and /or scattered in homestead which are retained and/or grown by the farmers governed by their own perceptions and beliefs about the beneficial attributes of trees. Multistoried agroforestry systems are predominant in Assam. Broadly existing agroforestry system of the study area has been categorized: agrisilvicultural and agri-silvi-horticulture, silvipastoral and silvihorticulture systems. Diagnostic survey reveals many constraints. Possible solutions to enhance productivity of agroforestry systems have been suggested.

Key words: agroforestry, agri-silvi-horticulture, silvihorticulture, silvipastoral systems

INTRODUCTION

Sustainability has different meanings to different people. The firm concern of any society is to provide food, fuel, fodder, fiber, timber and other daily needs of the fast growing human population and their livestock from the limited resources which are shrinking and also depleting due to heavy population pressure. The aim of sustainable development in agriculture /forestry or in other fields should be able to produce enough to meet the demand and needs of society and at the same time maintain /enhance the production potential of the land use system. Agroforestry system is a good option to meet the basic needs of a rural society (RAINTREE, 1990). The integration between forestry and agriculture has been vogue in Assam long before the term Agroforestry was coined. In Assam home garden represents land use system involving shrubs in intimate association with annual and perennial agricultural crops and invariably livestock, within the compound of individual houses, the whole crop tree-animal unit being intensively managed by family labour.

This paper includes a micro level diagnostic survey conducted to identify, classify, evaluate the existing agroforestry systems in North Lakhimpur district of Assam and the role of agroforestry systems for the sustainable development of the villages selected under the study.

MATERIALS AND METHODS

The study was carried out in three villages i.e., Rangajan no. 2, Hinda nop. 2, Azad of North Lakhimpur district of Assam. The villages are located at the distance of 10 km from the Lakhimpur main town. The North Lakhimpur district lies in between the longitude 95°42' to 94°38' and latitude of 26°49' to 27°37'. The total area of the district is 2277 km^2. The area receives average annual rainfall of 1051 mm. The maximum temperature in area goes up to 35°C and minimum up to 10°C.

To collect the data a schedule was prepared covering different aspects of agroforestry like socio-economic problems, land use statistics and soil characteristics. A list of house holds in that area of the selected village was prepared using random sampling with replacement method so as to remove bias in selection of farmers. Twenty farmers were selected from each village. Selection of households was completely random. Pre-structured survey schedules were used for the purpose of personal interview. Based on the size of their operational holdings, selected farmers were divided into four categories i.e., marginal (less than 1 ha.), small (1-2 ha), medium (2-10 ha), large (more than 10 ha).

Efforts were made to sample soils of the area. Soil samples were collected under various land use systems and were analyzed for the pH and type of soil. The soil of the area is found to be loamy sand. The soil is rich in nitrogen content. The pH of the soil is between 5-5.2. The agroforestry systems were classified on the basis of structure and function (NAIR, 1987). Biological yield was calculated by taking into account the harvestable and utilizable biomass from each functional unit of different component in every agroforestry system . These values were summed up and the average was taken to represent the biological yield. The total return from each system was determined by considering the utilizable biomass from each functional unit in a system type. Total investment incurred on production and cultural management has been taken into account to estimate the net economic return.

RESULTS AND DISCUSSION

Identification of agroforestry systems under the study area, the system of agroforestry found or preferred by farmers varied as per the category of farmers. Broadly, in almost all the home stead the following systems were identified followed by different categories of farmers of the study area:
- Agri-silviculture system.
- Agri-silvi-horticulture system.
- Silvi-pastoral system.

Silvi-horticulture system

Tab. 1 gives the type functional units of major of components in the agroforestry systems practiced by the three categories of farmers.

Agri-silviculture system

This system is the most common of all the systems. Trees were grown in and around agricultural fields.

TABLE 1
Agroforestry systems followed by different categories of farmers and its component and functional units.
Tipi di sistemi agroforestali e suoi componenti ed unità funzionali adottati dalle diverse categorie di agricoltori.

Category of farmers	Agroforestry system	Major component	Functional units
Small farmers	Agri-silviculture	Agriculture	*Oriza sativa, Avena sativa*
	Silvi-horticulture	Vegetable	Potato, Mustard, Chili, Tomato, Colacasia, Mung Dal
		Tree	*Tamarindas indica, Emblica officinalis*, *Bombax ceiba, Artocarpus integrifolia*
	Silvi-pastoral	Tree	*Artocarpus integrifolia, Acacia nilotica*
		Fruit	Guava, *Syzigium cumini*, *Mangifera indica, Banana, Zizyphus* spp., coconut
		Tree	*Bambusa* spp. *Subabul, Avena stiva, Dalbergia latifolia, Artocarpus integrifolia, Azadirechta indica*
		Pasture	Natural grass
Medium farmers	Agri-silviculture	Agriculture	*Oryza sativa*
		Vegetable	Carrot, Potato, Pea, Turmeric, Ginger
		Tree	*Artocarpus integrifolia, Bombax ceiba, Morus alba*
	Agri-silvi-horticulture	Agriculture	Mustard, *Oryza sativa*
		Tree	*Dellinia indica, Bombax ceiba, Albizzia, Dalbergia latifolia, Bambusa* spp., Ficus, Subabul
		Fruit	Pineapple, Citrus, Mango, Banana, Ber Jackfruit, Arecanut, Aeglemarmelos, Borassus
Large farmers	Silvi-pastoral	Pasture	Natural grasses
		Tree	*Erythrina, Lagestroemia speciosa, Morus alba, Acacia nilotica, Tamarindus indica,* Jackfruit
	Silvi-horticulture	Tree	Subabul, Jackfruit
	Agri-silvi-horticulture	Fruit	Arecanut, Coconut Pineapple, Amla
		Agriculture	*Oryza sativa*
		Vegetable	Carrot, Colacasia, Ginger, Turmeric, Cucumber, Black gram
		Fruit	Arecanut, Coconut
		Tree	Jackfruit, Neem, *Bombax ceiba, Morus alba*

Basically line planting is followed with a spacing of 8 x 8 m. This system provides good income to the farmers. However farmers sell vegetables such as potato, mustard, tomato, chili, though in small quantities.

Agri-silvi-horticultural system

This system is found to be the most widely preferred by farmers. Under this system, agricultural crops are grown along with forest and fruit species. Medium and large farmers practiced this system in a prominent way. Arecanut is found to be the most profitable crop, since it fetches good returns.

Silvi-horticultural system

Under this system, forest species are grown along with horticultural crops. *Bombax ceiba, Artocarpus*, are the most common among silvicultural group. *Guava arecanut,* coconut, pineapple are common among the horticultural group. Horticultural crops are grown mainly for fulfilling their own needs.

Silvi-pastoral system

This system is found to be common in almost all the categories of farmers. Lopping of tree species is done and the grasses and bushes of the understorey are used for grazing.

Livestock is also an integral part of the agroforestry system of this area. Livestock such as fowls, pigs, buffalo, bullock, goats and other cattle are reared by the farmers. All the livestock were of local varieties. Burning debris in the field, use of cowdung and other animals wastes and use of NPK in the field were some of the management practices adopted by farmers to maintain soil fertility.

In these systems types, major functional unit in agriculture component consisted of *Oryza stiva*, *Avena sativa,* potato, mustard, tomato, *Colocacia*, carrot, ginger, turmeric, cucumber, blackgram and mung dal. Oilseeds includes mustard; the vegetables potato, tomato, carrot and cucumber and the pulses include blackgram and mung dal. Citrus, guava, banana, arecanut, mango, ber, jackfruit, coconut, pineapple and aonla represented the major horticulture components. In the forestry components, subabul *Bombax ceiba, Artocarpus integrifolia, Acacia nilotica, Dalbergia latifolia, Albizia* and *Bambusa* (Bamboo) from the major functional units. These system are mainly managed for subsitance only. Some trees have been planted and retained in the field boundaries for fuel wood and fodder. Natural grasses found under field bunds are cut and fed to the animals.

Biological and economic returns from agroforestry systems

The average land holding under agriculture was by far the largest among all the three categories of farmers (Tab. 2) followed by forest area and pasture. Area occupied by orchards were least among all the farmers. Socio-economic status of the farmer reflects the type of agroforestry system/land use pattern and also the management practice adopted. Some of the socio-economic features existing in the area have been summarized in Tab. 3, 4 and 5.

Education status of the farmers indicates that approximately 38% of them are literate. The literacy rate was highest among large farmers and least among small land holders. Average family size was least in medium farmers and largest among small land holders (Tab. 3).

People in these villages mainly rear cows, bullocks, buffaloes, goats, chicken and pigs all of which are of local breeds. The cows are mainly kept milk and meat. Buffaloes are reared for milk and are also used as draft animals along with bullocks. Adult cattle unit (ACU) was calculated as per Yang (1971). The least adult cattle unit was observed for small farmers and highest for the large farmers (Tab. 4).

TABLE 2

Distribution of different classes of land holdings among the three categories of farmers.
Distribuzione delle diverse classi di proprietari di terreno presenti in tre categorie di agricoltori.

Category of farmers	Average Area (ha)				
	Agriculture	Pasture	Orchard	Forest	Total
Small	0.80	0.1	0.05	0.19	1.14
Medium	4.32	0.3	0.09	0.22	4.93
Large	20	3.0	0.16	6.8	29.96

TABLE 3

Family size and educational status for different categories of farmers.
Composizione del nucleo familiare e formazione scolastica in tre categorie di agricoltori.

Category of farmers	Literacy rate	M:F Ratio	Avg. family size (no)
Small	20%	1:2	20
Medium	33%	1:0.96	9
Large	60%	1:0.31	12

TABLE 4

Livestock pattern (per household). ACU = Adult Cattle Unit; Cow, buffalo, horse = 1 ACU; Buffalo = 1.3 ACU; Young stock = 0.75 ACU; Goat = 0.15 ACU.
Composizione del patrimonio zootecnico (per azienda). ACU = Unità di bovini adulti; Cow, buffalo, horse = 1 ACU; Buffalo = 1.3 ACU; Young stock = 0.75 ACU; Goat = 0.15 ACU.

Category of farmers	Cow	Bullock	Buffalo	Young stock	Goat	Total ACU	Poultry	Pig
Small	4	2	3	2	1	11.25	10	7
Medium	9	1	6	5	2	20.35	22	21
Large	19	5	4	16	16	42.55	49	33

TABLE 5

Annual fodder production, consumption, requirement among the farmers.
Produzione, consumo e fabbisogno annuo di foraggio in tre categorie di agricoltori.

Category of farmers	Consumption per household (Quintal)	Production per household (Quintal)	Requirement (Quintal)	Percent deficit over	
				Consumption	Production
Small	200.50	43.2	1149.75	82.56	96.24
Medium	675.25	262.92	2079.77	67.32	87.36
Large	1473.60	789.81	4348.61	66.11	81.84

Average consumption of fodder is about 200.50 quintals and production is only 43.2 quintals as against the requirement of 1149.75 quintals among small farmers. Suggesting a deficit of 82.56% in consumption and 96.24% in production. The consumption and production deficits are least among the large farmers (Tab. 5). This deficit is mitigated by collecting fodder from nearby forest areas or purchasing it from local market. However, animals are also allowed to graze freely on free available land in the neighborhood. Due to the shortage of fodder and poor animal husbandry facilities the farmers are not able to sustain improved breeds of cattle or fowl but are forced to keep the local variety only.

Tab. 6 reveals that of four different agroforestry systems the maximum biological yield is produced in the agri-silvi-horticultural system (1005.33 quintals), followed by silvi-horti systems. Agri-silviculture system and agri-silvicultural system and silvi-pastoral system in the order given. Some trend is also seem for the net economic returns. Maximum net economic returns are obtained from agri-silvi-horticultural system and the least from silvi-pastoral system.

Agroforestry and sustainable development

Sustainability is treated synonymous with sustainable production. Though food production has increased manifold it does not guarantee food security at house hold level. Agriculture is main stay of the people of Assam but the plight of the majority of its farming communities is pathetic. The ray of green revolution has not been able to illuminate the dark farming systems of the state. Mechanization is yet to begin in this section. Poverty being a multifaceted phenomenon, requires to be tackled through multi project strategies with ecological compatibility. Poverty is the end of inadequate and insufficient utilization of the capacity of the society as a whole.

Hence, economic development is to be woven around the major components of society i.e., natural resource, human resource and social values and agroforestry will be vital for bridging the gap between demand and availability of various forms of products which are required for the sustenance of humans in a healthy society (DEBROY, 1994).

TABLE 6

Biological and economical returns from different agroforestry systems.
Resa biologica ed economica dei diversi sistemi agroforestali.

Agroforestry system	Biological yield (q)	Gross return (Rs)	Net return (Rs)
Agri-silvi-horti	1065.33	608979.52	58752.52
Silvi-horti	112.88	65025.1	52470.1
Silvi-pastoral	121.92	28114.25	15958.55
Agri-silvi	97.35	583400.8	44050.8

It was found that agroforestry is an integral part of almost every household in the area of our study. The existing system has been able to provide sound economic net return to some extent in comparison to other areas. It is very much imperative that if the existing system can be managed scientifically providing inputs which may yield ample biological yield then it is bound to ensure sustained development.

Constraints

On the basis of diagnostic survey and appraisal of the existing agroforestry systems, it is found that the following are the aspects which need immediate attention:

- Farmers practice subsistence farming.
- There is a great population pressure.
- Absence of govt. authorized sale center.
- Complex procedures in acquiring modern mechanized facilities.
- Cattle's were of local varieties giving low level of return.
- Inadequate irrigation facilities.
- Application of agricultural chemicals like fertilizers, pesticides is very uncommon.
- Lack of continuity in the information transmission.
- Flood is very frequent: this particular fury of nature visits the area every year which destroys the set-up of previous year.

Suggestions

Based on the need and constraints of land use the following suggestion can be made:

- Subsistence farming system should be replaced by scientifically managed agroforestry systems.
- In order to boosts the level of production, high yielding variety of crop should be raised.
- Improve animal husbandry practice should be adopted
- Pilot models should be designed to demonstrate holistic and integrated land use system under agroforestry.
- Side specific species of crops and tree should be introduced. Research and development should be strengthened.
- Non-timber forest produce (NTFP) should be commercialized.
- Cooperatives should be opened up to smooth marketing of the produce of farmers.
- Orientation training program should be organized to impart the latest knowledge to the farmer.
- The agricultural crops need to be insured under any insurance company.
- This may reduce the agony of farmers due to floods/or any other natural calamities.

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RIASSUNTO - Le pratiche agroforestali, come approccio integrale all'uso del territorio, esistono da tempo immemorabile nell'area di Assam. Oggigiorno le pratiche agroforestali sono molto diffuse in Assam e ciò si evince dalla presenza di alberi lungo i confini delle aziende, e/o sparsi intorno alle fattorie, che sono allevati dagli agricoltori in base alla loro percezione e credenza relativa agli attributi benefici degli alberi. I sistemi agroforestali predominanti in Assam sono molteplici. In generale, i sistemi agroforestali esistenti nell'area oggetto di studio sono stati classificati come: sistemi agro-silvicolturali e agro-silvi-orticolturali, sistemi silvi-pastorali e silvi-orticolturali. Un'indagine diagnostica rivela però molteplici limitazioni negli attuali sistemi agroforestali. In questo lavoro vengono suggerite possibili soluzioni atte ad aumentare la produttività dei sistemi agroforestali.

AUTHORS

B. Singh, K.K. Sood, D. Bora, H. Prasad, P. Rethy, North Eastern Regional Institute of Science and Technology, Nirjuli 791 109Arunachal Pradesh, India

Comparative study on understorey vegetation develop of Chinese fir plantations of different generation

S.H. FAN, Q. MAX, L.H. FU and A.Q. LIU

ABSTRACT - We investigated the composition and age of the understorey vegetation of Chinese fir plantations of different generation. The results shows that understorey vegetation development of Chinese fir plantations is greatly influenced by the planting generation. There are significant differences among the understorey vegetation species, and in their frequency and biomass, of different generation plantations. The number of species of the first, second, and third generation plantations are 69, 54, and 59, respectively. As planting generation increases, the biomass accumulation and the nutrient concentration of understorey vegetation increase. Compared to the first generation plantations, the nutrient concentration of the understorey vegetation of the second and the third generation plantations increased by 16.90% and 37.49%, respectively. However, despite differences in the nutrient concentration among generation plantations, we may conclude that in general the understorey vegetation of Chinese fir plantation has high capacity to accumulate nutrients.

Key words: Chinese fir, planting generation, soil degradation, understorey vegetation

INTRODUCTION

Understorey vegetation, as an important component of plantation ecosystem, plays a key role in maintaining the nutrient cycling of forestland and recovering the soil fertility. With the increasing decline of productivity of successively planted Chinese fir plantation, more attention has been paid on the understorey vegetation of Chinese fir. But less study was conducted on the comparison of understorey vegetation development of Chinese fir plantations of different generations and different development stages. The Chinese fir plantations of different generations (the first, the second and the third generation), development stages (in the fifth, tenth, fifteenth and twentieth year), sites (site index of 14, 16, and 18) were selected from China's main production area of Chinese fir, and a comparative study was conducted on the variety, quantity and nutrient accumulation of understorey vegetation, which may provide some references for revealing the vegetation development pattern of Chinese fir plantation of different generations and its influence on controlling soil degradation.

This study is a component part of the study on the productivity of successively planted Chinese fir plantation by means of spatial sequence method (FAN *et al.*, 2000; MA *et al.*, 2000; FAN, MA, 2001; MA *et al.*, 2001). The principal patterns of understorey vegetation development of Chinese fir plantations of different planting generations and different development stages are introduced in this paper.

MATERIALS AND METHODS

General condition of experimental area

Experimental plots are located in Jingying Forestry Farm of Youxi County, Fujian Province, China, which is the central production area of Chinese fir plantation (25°48' N 26°24' N, 117°48' E 118°36' E). The plot belongs to subtropical monsoon climate, the annual mean precipitation is 1599.6 mm, and the annual evaporation capacity 1323.4 mm, the relative moisture 83%, annual air temperature 18.9 °C, the largest daily precipitation 131.7 mm, the period from March to June is the rainy season, which accounts 56% of annual precipitation.

Design of standard plots

The results of study showed that the site index of Chinese fir plantation decreases by one site index after one rotation. So forestland as the first generation Chinese fir plantation with site index of 18, the second generation plantation site index of 16 and the third generation plantation site index of 14 are selected in the study in order to assure that every plot belongs to 18 site index in the first generation; and the same distribution area of Chinese fir, climate, mother material, mother rock and management condition are requested in selected standard plots.

Standard plots are established by selecting different generations (the first, the second, the third generation), different site index (site index of 14, 16 and

18) and different ages (5, 10, 15, 20, years old) Chinese fir plantations.

Increment investigation

To Locate 20 m x 20 m standard plot in every plot, measure the height and D.B.H of every tree, identify site index on the basis of stand age, height of dominant tree and site index of Chinese fir.

Biomass investigation

To select 1-3 standard trees according to average-standard-tree method, when felled, intercept circumstance plate in section in terms of 1 M, weigh the leaf, branch, stem, bark and root respectively, measure water content and nutrition of every sample.

Under forest vegetation investigation

To locate 3-5 quadrates in standard plot, investigate vegetation species, quantity, consequence degree, canopy and height of vegetation, measuring biomass of ground vegetation (shrubbery layer and herb layer) and forest floor with the method of quadrate yield and measure water content and nutrition of every sample.

Results

According to the investigation, understorey vegetation includes 118 species in different developing stage and different generation plantation, among which, 9 species of *Pteridophyta*, 2 species of *Gymnospermae*, 107 species of *Angiospermae*, 21 species of young tree of arboreous layer, 61 species of shrubbery, 24 species of herb, 13 species of wine vegetation (Tab. 1-4).

TABLE 1
Understorey vegetation species quantities of Chinese fir plantations of different generation and age.
Numero di specie di piante presenti nel sottobosco di piantagioni di abete cinese di diversa generazione e di diversa età.

Vegetation type	First generation					Second generation					Third generation				
	5	10	15	20	average	5	10	15	20	average	5	10	15	20	average
Young tree	14	12	9	10	11	8	5	8	9	8	65	5	9	8	7
Shrub	30	26	40	42	35	23	20	30	34	27	27	22	33	37	30
Grass	10	15	16	15	14	11	13	13	14	13	12	15	16	17	15
Between layers	5	9	10	11	9	4	5	8	9	6	4	5	11	9	7
Total	59	62	75	78	69	46	43	59	66	54	49	47	69	71	59

TABLE 2
Arboreous species of underground vegetation in Chinese fir plantations of different generation and age.
Specie arboree presenti nel sottobosco di piantagioni di abete cinese di diversa generazione e di diversa età.

No.	Scientific name	First generation				Second generation				Third generation			
		5	8	15	19	6	9	15	19	6	9	16	22
1	*Machilus grijsii*	℘	℘	℘	℘	℘	℘	℘	℘		℘	℘	℘
2	*Ormosia xyloccarpa*		℘		℘					℘			
3	*Sassafras tzumu*	℘	℘		℘	℘	℘		℘				
4	*Machilus pauhoi*			℘				℘				℘	
5	*Schima superba*	℘	℘		℘	℘	℘	℘		℘		℘	℘
6	*Cycobalanopsis changii*		℘										
7	*Cycobalanopsis eyrei*	℘		℘				℘					
8	*Castanopsis cartesii*	℘			℘	℘							
9	*Daphniphyllum oldhamii*		℘	℘			℘						
10	*Elaeocarpus chinensis*		℘	℘	℘		℘		℘		℘		
11	*Cycobalanopsis glauca*	℘		℘									
12	*Alniphyllum fortumei*	℘	℘	℘	℘		℘	℘	℘		℘	℘	
13	*Machilus velutina*	℘	℘		℘		℘	℘		℘			
14	*Firmiana simplex*	℘		℘		℘					℘	℘	
15	*Diospyros morrisiana*	℘	℘	℘	℘		℘	℘		℘	℘		
16	*Diospyros kaki*	℘			℘				℘		℘		
17	*Lithocarpus glaber*		℘				℘					℘	
18	*Castanopsis fargesii*		℘		℘			℘		℘		℘	
19	*Pinus massoniana*	℘				℘			℘		℘		
20	*Vernicia fordii*	℘		℘	℘	℘			℘		℘		
21	*Cunninghamia lanceolata*					℘	℘		℘	℘			

TABLE 3
Shrub species of understorey vegetation in Chinese fir plantations of different generation and age.
Specie di cespugli presenti nel sottobosco di piantagioni di abete cinese di diversa generazione e di diversa età.

No.	Scientific name	First generation				Second generation				Third generation			
		5	8	15	19	6	9	15	19	6	9	16	22
1	*Earya hebedados*		℘	℘	℘		℘	℘				℘	℘
2	*Adinandra mellettii*	℘	℘	℘	℘	℘		℘	℘	℘		℘	℘
3	*Ardisia punctata*	℘	℘	℘	℘	℘	℘		℘	℘	℘		
4	*Ilex pubescens*	℘	℘	℘		℘	℘	℘		℘	℘	℘	
5	*Hydrangea lingii*		℘		℘			℘			℘	℘	
6	*Carex cruciata*		℘		℘		℘			℘			
7	*Aralia spinifolia*	℘		℘		℘			℘				
8	*Litsea green maniana*	℘	℘	℘	℘			℘					
9	*Styrax faberi*			℘	℘		℘		℘	℘	℘	℘	℘
10	*Rhododendron simsii*	℘		℘	℘							℘	
11	*Symplocos lancifolia*			℘			℘		℘	℘		℘	
12	*Rubus tsangorus*	℘	℘	℘	℘		℘		℘		℘	℘	
13	*Vaccinium carlesii*		℘	℘		℘		℘	℘	℘	℘	℘	
14	*Homalium cochinchinensis*		℘			℘	℘	℘					
15	*Rubus alceaefolius*			℘	℘				℘	℘	℘		
16	*Ampelopsis grossedencata*	℘	℘			℘	℘	℘		℘	℘		
17	*Ilex triflore*			℘	℘		℘			℘		℘	
18	*Lindera aggregata*	℘		℘	℘	℘		℘	℘	℘		℘	℘
19	*Callicarpa kochiaha*		℘	℘	℘	℘		℘		℘	℘	℘	
20	*Rubus reflexus*	℘	℘		℘		℘	℘	℘		℘	℘	
21	*Randia cochinchinensis*	℘		℘	℘								
22	*Ilex kwang*		℘	℘	℘		℘		℘		℘		
23	*Itea chinensis*	℘	℘	℘	℘	℘		℘	℘	℘		℘	℘
24	*Meliosma rigide*		℘		℘			℘		℘		℘	
25	*Symplocos sumuntia*	℘		℘			℘		℘		℘		
26	*Camellia cuspidata*			℘	℘		℘		℘				
27	*Rubus rosaeflius*	℘	℘	℘	℘	℘	℘		℘		℘		℘
28	*Rapanea neriifolia*	℘		℘			℘	℘			℘		
29	*Alpinia japonica*			℘						℘			
30	*Ficus stenophylla*			℘	℘							℘	
31	*Symplocos grandis*	℘	℘	℘	℘			℘	℘		℘	℘	
32	*Maesa japonica*		℘	℘	℘	℘	℘	℘		℘	℘	℘	℘
33	*Syzygium buxifolium*	℘		℘	℘	℘		℘	℘	℘	℘	℘	℘
34	*Sapium discolar*	℘	℘	℘	℘	℘		℘	℘	℘	℘		
35	*Photinia Prunifolia*	℘		℘	℘		℘		℘			℘	℘
36	*Vaccinium bracteatum*	℘	℘	℘	℘	℘		℘	℘	℘		℘	℘
37	*Disty liopsis*			℘	℘			℘			℘	℘	
38	*Toxicodendron succedaneum*	℘	℘	℘	℘	℘		℘	℘	℘	℘		
39	*Heteropanax brevipedicellatus*	℘		℘			℘				℘		
40	*Viburnum dilatatum*			℘	℘	℘	℘		℘		℘		
41	*Eurya nitida*		℘	℘	℘	℘		℘	℘	℘		℘	℘
42	*Helicia cochinchine*	℘		℘	℘							℘	
43	*Ilex dasyphylla*			℘					℘	℘			
44	*Antidesma japonicum*			℘	℘	℘		℘			℘		
45	*Camellia oleifera*				℘	℘		℘	℘	℘		℘	℘
46	*Symplocos laurina*		℘	℘						℘			
47	*Neolitsea brevipesi*	℘		℘			℘						
48	*Celastrus aculeatus*	℘		℘	℘	℘	℘	℘	℘	℘		℘	℘
49	*Urena procumbens*		℘		℘		℘		℘		℘	℘	
50	*Rhus chinensis*	℘	℘		℘	℘		℘	℘	℘		℘	℘
51	*Ficus birta*	℘		℘	℘	℘		℘	℘	℘	℘	℘	℘
52	*Pleioblastus amarus*						℘					℘	
53	*Loropetalum chinensis*				℘	℘		℘	℘	℘		℘	℘
54	*Litsea cubeba*	℘			℘	℘		℘	℘	℘	℘	℘	℘
55	*Phyllostachys flexuosa*						℘	℘	℘			℘	
56	*Ardisia crispa*	℘			℘		℘			℘			
57	*Indocalamus longiaurillus*	℘			℘	℘		℘	℘	℘	℘	℘	℘
	Total	30	26	40	42	23	20	30	34	27	22	33	37

TABLE 4
Grass species in Chinese fir plantation of different generation and age.
Specie di piante erbacee presenti nel sottobosco di piantagioni di abete cinese di diversa generazione e di diversa età.

No.	Scientific name	First generation				Second generation				Third generation			
		5	8	15	19	6	9	15	19	6	9	16	22
1	*Miscanthus sinensis*	℘	℘	℘				℘	℘	℘		℘	℘
2	*Miscanthus floridulus*				℘	℘		℘			℘	℘	
3	*Lophatherum gracice*	℘	℘	℘	℘	℘	℘	℘		℘	℘	℘	℘
4	*Woodwardia japonica*	℘	℘	℘	℘	℘	℘	℘	℘	℘	℘	℘	℘
5	*Stenoloma chusana*		℘	℘	℘		℘		℘	℘	℘	℘	℘
6	*Cyrtococcum patens*		℘	℘			℘	℘	℘		℘		
7	*Melastoma dodecandrum*	℘	℘	℘	℘	℘	℘	℘		℘	℘		
8	*Hedyotis chrysotricha*		℘							℘	℘		
9	*Gahnia tristis*		℘	℘	℘	℘	℘	℘	℘	℘	℘	℘	℘
10	*Lygodium japonicum*		℘	℘	℘		℘	℘		℘	℘		
11	*Lindsaea orbiculata*		℘	℘	℘	℘	℘	℘		℘	℘		℘
12	*Parathelypteris glanduligera*			℘				℘		℘			
13	*Sarcandra glabra*	℘	℘	℘	℘	℘		℘	℘		℘		
14	*Setaria palmifolia*		℘	℘				℘		℘			
15	*Blechum orientale*		℘	℘		℘	℘		℘	℘		℘	
16	*Lycopodium cernuum*		℘	℘	℘		℘	℘	℘		℘		℘
17	*Adiantum flabellulatum*		℘	℘	℘	℘	℘	℘	℘	℘	℘	℘	℘
18	*Arthraxon hispidus*	℘	℘			℘		℘					
19	*Selaginella doeclerleinii*	℘	℘		℘	℘	℘	℘	℘	℘	℘	℘	℘
20	*Millettia reticulata*	℘	℘										
21	*Hicriopteris chinensis*				℘	℘		℘			℘	℘	
22	*Dicranopceris dichotoma*	℘	℘	℘	℘	℘	℘	℘	℘	℘		℘	℘
23	*Clerodendrum cyrtophyllum*	℘		℘						℘	℘	℘	
24	*Dianella ensifolia*	℘			℘					℘	℘	℘	
25	*Blumea megacephala*	℘			℘					℘	℘		
	Total	10	15	16	15	11	13	13	14	12	15	16	17

The number of species of the first generation plantation are 69; the number of species of the second generation plantation declined to 54 species; young tree of arboreous layer and shrubbery species which initial community left decreased considerably or disappeared because of disturbance of forest management such as continuously prescribed burning and site preparation. The young tree of arboreous layer and shrubbery species were 8 species and 27 species respectively; while understorey vegetation species abundance in the third generation plantation increased slightly (59 species), which is concerned with bad growth in the third generation plantation and considerable sporadic crown of forest.

Concerning the vegetation species, 118 vegetation species in the investigated plots of this study exist in various generation plantations and there is no special species in different generation plantation. But there existed difference on the frequency degree of species. The variation law of understorey vegetation in plantation with different developing stages is regular. When 5-year-old stand enter close canopy, the crown of Chinese fir appear sharp- tower, and understorey species abundance is as high as about 46-59 species, especially some intolerant shrubbery.

Then, as young Chinese fir plantation grew, the illumination in the forest decreased in 10-year-old Chinese fir forest, the heliophyte was replaced by sciaphyte vegetation, and shrubbery decreased significantly. On the contrary, some shade grass species increased slightly. When 15-years-old, crown of Chinese fir become ball-shape due to intermediation and nature cleanliness, and its understorey vegetation species increase significantly. Vegetation species between layers increase as understorey vegetation recover and number of understorey vegetation increased. It is a benefit for recovery of soil fertility. However, felling will be made according to traditional plantation management at this stage, which disturbs the recovery of forestland vegetation and soil fertility.

The proportion of species of different understorey vegetation layer in different generation plantation varies. As planting generation increases, the proportion of young tree of arboreous layer and shrubbery decreases. However, the proportion of species of shrubbery layer increases, and the proportion of species between layers does not vary significantly, the proportion difference of understorey vegetation composition in different generation plantation is related to the growth of different generation plantation. Tab. 5 shows that the proportion of shrubbery among understorey vegetation composition in different developing stage and generation plantation is the highest and in the sequence of shrubbery layer > grass layer > young tree of arboreous layer > interlayer vegetation, which indicates that the vegetation of shrubbery is still dominant among understorey vegetation of Chinese fir plantation (Tab. 5).

Differences exist not only in understorey vegetation species in different generation plantation, but also in understorey vegetation biomass. As planting generation increases, the biomass of understorey shrubbery layer, grass layer, and floor layer increase. In 20-year-old Chinese fir forests, compared to the first generation, the biomass of ground vegetation and litterfall of the second generation decrease by 4.32% and 20% respectively. Those of the third generation decrease by 27.38% and 19.15% respectively. It shows that stand growth of the second generation and the third generation is not well and the forest form is not uniform after successive planting. However, it is a benefit for the development of understorey vegetation and recovery of soil fertility. This may be the response of Chinese fir plantation ecosystem to the stimulation of soil degradation after successive planting (Tab. 6).

The biomass of understorey vegetation in plantations with different developing stage has obvious law. After Chinese fir plantation is cultivated, its understorey vegetation biomass increases. The average biomass of five-year-old plantation is 1.4 t/hm^2,

TABLE 5

Proportions of different vegetation layers in Chinese fir plantations of different generation and age (%).
Percentuale dei diversi strati di vegetazione presenti nel sottobosco di piantagioni di abete cinese di diversa generazione e di diversa età.

Vegetable	First generation					Second generation					Third generation				
type	5	10	15	20	average	5	10	15	20	average	5	10	15	20	average
Young tree	23.73	19.35	12	12.82	16.98	17.39	11.63	13.56	13.64	14.81	12.25	10.64	13.04	11.27	11.86
Shrub	50.85	41.94	53.33	53.85	49.99	50.0	46.51	50.85	51.52	50.00	55.10	46.81	47.83	52.11	50.85
Grass	16.95	24.19	21.33	19.23	20.43	23.91	30.23	22.03	21.20	24.07	24.49	31.91	23.19	23.94	25.42
Interlayer vegetation	8.47	14.52	13.34	14.10	12.60	8.70	11.63	13.56	13.64	11.11	8.16	10.64	15.94	12.68	11.86
Total	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

TABLE 6

Biomass (t hm^{-2}) of understorey vegetation in Chinese fir plantations of different generation and age.
Biomassa (t hm^{-2}) della vegetazione del sottobosco di piantagioni di abete cinese di diversa generazione e di diversa età.

		Ground vegetation						Floor vegetation	
		Shrub layer		Grass layer		Total			
Generation	Age	Biomass	Proportion	Biomass	Proportion	Biomass	Proportion	Biomass	Proportion
1	5	0.84	38.35	0.39	17.81	1.23	56.16	0.96	43.84
2	6	0.98	39.68	0.45	18.21	1.43	57.89	1.04	42.11
3	6	1.05	39.92	0.49	18.63	1.54	58.55	1.09	41.46
average		0.96	39.32	0.44	18.22	1.40	57.53	1.03	42.47
1	8	0.35	16.91	0.34	16.42	0.69	33.33	1.38	66.67
2	9	0.42	17.87	0.40	17.02	0.82	34.89	1.53	65.11
3	9	0.59	23.04	0.45	17.58	1.04	40.62	1.52	59.38
average		0.45	19.27	0.40	17.01	0.85	36.28	1.48	63.72
1	15	1.46	26.99	0.69	12.75	2.15	39.74	3.26	60.26
2	15	2.14	32.92	0.87	13.39	3.01	46.31	3.49	53.69
3	16	2.52	33.24	0.97	12.80	3.49	46.04	4.09	53.96
average		2.04	31.05	0.84	12.98	2.88	44.03	3.61	55.97
1	19	2.55	32.03	0.92	11.56	3.47	43.59	4.49	56.41
2	19	2.65	32.32	0.97	11.83	3.62	44.15	4.58	55.85
3	22	3.17	32.45	1.25	12.79	4.42	45.24	5.35	54.76
average		2.79	32.27	1.05	12.06	3.84	44.33	4.81	55.67

then, as it enters close canopy, its understorey vegetation develops weakly and the average ground vegetation biomass of ten-year-old plantation only reaches 0.85 t/hm^2; finally, due to the effect of intermediation and natural pruning, penetrating light degree increase, understorey vegetation develop slightly and both its biomass of ground vegetation and biomass of forest floor increase, the average biomass of ground vegetation and average biomass of forest floor in fifteen-year-old plantations are 2.88 t/hm^2 and 3.61 t/hm^2 respectively, the average biomass of ground vegetation and average biomass of forest floor in twenty-year-old plantations are 3.84 t/ hm^2 and 4.81 t/hm^2 respectively. The variation law of understorey vegetation in Chinese fir forest influences soil fertility considerably.

Because understorey vegetation species in plantations in different developing stages and different generation are different, variation of nutrition concentration of ground and floor vegetation shows non-obvious law. Except Ca element, every element concentration of ground vegetation is higher than those of forest floor vegetation and higher than those of individual organ. It shows that ground vegetation is able to accumulate nutrition.

Nutrition accumulation of understorey ground and floor vegetation in different generations shows obvious law. As planting generation increases, both the nutrition content of ground vegetation and forest floor vegetation increase, among which, nutrition of ground vegetation accumulate significantly. Compared to the first generation plantation, nutrition accumulation of ground vegetation in the second and the third generation plantation increase by 6.96% and 37.49% respectively, nutrition accumulation of forest floor vegetation in the second and the third generation plantation by 5.63% and 20.28 % respectively. And compared to the second generation plantation, nutrition accumulation of ground vegetation and understorey forest floor vegetation in the third generation plantation increase by 17.62% and 13.87% respectively. From analysis mentioned above, it shows that though nutrition accumulation of arboreous layer decreases after successive planting, nutrition accumulation of understorey vegetation increases evidently, which is certainly a benefit for recovery of soil fertility .

Nutrition accumulation of ground and floor vegetation in plantation in different developing stages is different evidently. In young plantation (before ten years old) nutrition accumulation of accumulation of forest floor vegetation increase; then both the nutrition accumulation of ground vegetation and forest floor vegetation increase considerably in middle aged forest and in mature forest, and compared to five-year-old Chinese fir plantation, nutrition accumulation of ground vegetation and forest floor vegetation of twenty-year -old Chinese fir plantation increase by 178.58% and 359.85% respectively. It shows that mature forest is beneficial for nutrition accumulation of understorey ground and floor vegetation. Delay rotation is beneficial for recovery of soil fertility.

CONCLUSION

Not only understorey vegetation species and consequence degree in different generation plantation, but also the biomass of understorey vegetation are different. Species abundance of understorey vegetation in the first, the second and the third generation plantation are 69 species, 54 species and 59 species respectively. As planting generation increases, biomass of understorey ground vegetation and of understorey forest floor vegetation increase. It shows that successive planting is certainly a benefit for the development of understorey vegetation and recovery of soil fertility .

Nutrition concentration of understorey ground and forest floor vegetation has no evident regularity, but the nutrition accumulation law of understorey ground and forest floor vegetation is different. Nutrition accumulation of understorey ground vegetation and forest floor vegetation increase as planting generation. Nutrition accumulation of ground vegetation increase significantly, and compared to the first generation plantation, nutrition accumulation of ground vegetation in the second generation plantation and in the third generation plantation increase by 16.90% and 37.49% respectively. Meanwhile nutrition accumulation of forest floor vegetation increase by 5.63% and 20.28% respectively. This may be the response of Chinese fir plantation ecosystem to soil degradation.

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RIASSUNTO – In questo studio si è analizzata la composizione e l'età della vegetazione del sottobosco presente nelle piantagioni di diversa generazione di abete cinese. I risultati mostrano che il tipo di vegetazione del sottobosco di abete cinese è fortemente influenzato dalla generazione della piantagione. Infatti, si sono trovate differenze significative tra piantagioni di diversa generazione nelle specie presenti nella vegetazione del sottobosco, nella loro frequenza e nella loro biomassa. Il numero delle specie presenti nel sottobosco delle piantagioni di prima, seconda e terza generazione sono rispettivamente 69, 54 e 59. Al crescere della generazione della piantagione, l'accumulo della biomassa e la concentrazione dei nutritivi della vegetazione del sottobosco aumenta. La concentrazione dei nutrienti della vegetazione del sottobosco presente nelle piantagioni di seconda e terza generazione è risultata rispettivamente il 16.90% e 34.49% più alta di quella della vegetazione del sottobosco presente nelle piantagioni

di prima generazione. Nonostante le differenze esistenti tra le piantagioni di diversa generazione, si può comunque concludere che in generale la vegetazione presente nel sottobosco delle piantagioni di abete cinese ha una elevata capacità di accumulo dei nutrienti.

AUTHORS

Shao Hui Fan, Q. Ma X, L.H. Fu, A.Q. Liu, Research Institute of Forestry, CAF, Beijing, 100091, China

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Pathways to the wise management of forests in Europe: trends in research for sustainability

F.O. ANDERSSON

ABSTRACT - EFERN, European Forest Ecosystem Research Network, was set up in 1996 as one result of the Ministerial Conferences on the Protection of European Forests in Strasbourg 1990 and Helsinki 1993 with the aim of promoting ecological research for sustainable forest management. The intention was also to give priorities for future forest ecosystem research. In accepting the idea that sustainability includes a multifunctional view of forests, there is a need to find ways of integrating classical forest ecosystem research with biodiversity, water quality and socio-economics. The balancing of the different interests in the forests can be done through planning. From this results also a choice of adequate management methods of the forest resources. The classical stand level in forestry requires now an additional scale - the landscape level. The aim with this paper is to present a concept, which attempts to integrate disciplines involved - ecosystem and landscape ecology and its components. Areas where research and development efforts are central are also mentioned.

Key words: biodiversity, EFERN, forest ecosystem, forest management, multifunctionality, sustainability

INTRODUCTION

Forests in Europe are of concern for a sustainable development of the Society. At the Third Ministerial Conference on the Protection of Forests in Europe (Lisbon, June 1998) the Ministers responsible recalled the forest-related decisions taken at the global level, notably at the UNCED (Rio de Janerio, 1992) and shared the following vision (Lisbon General Declaration - Vision - Paragraph 1):

"In the 21 century, the European forest sector, while respecting social, economic, environmental and cultural functions of forests, will optimise its contribution to the sustainable development of Society, especially to the development of rural areas, the provision of renewable resources and the protection of the global environment".

The forest damage or syndrome during the 1970 and 1980´s in West Europe led to an increased concern for the conditions of the forests in Europe. The Ministerial Conference mentioned was then initiated and met for the first time in 1990 and the second time 1993. A number of resolutions have been taken (ANONYMOUS, 2000a) and the result of 10 years commitment have also been described (ANONYMOUS, 2000b). In this paper the achievements made as a result of one of those resolutions taken at the First Ministerial conference, it's Resolution no. S 6 "European Network for Research into Forest Ecosystems" in 1990 will be presented.

EFERN: EUROPEAN FOREST ECOSYSTEM RESEARCH NETWORK

The starting point of the European Forest Ecosystem Research Network, EFERN, is the resolution 6 of the Strasbourg Ministerial Conferences on the Protection of Europe's Forests. In order to promote a sustainable use of forests the signatory states and international institutions among other things committed themselves to better combine their research efforts at the international level, to set up a European network for research on forest ecosystems, and definition of a few research subjects particularly for the protection of Europe's forests.

At a meeting in 1995 held in Warsaw, Poland, where 20 European nations were represented, it was decided to apply for a Concerted Action within the EU - Food and Agriculture Programme (FAIR) within the 4th Framework programme. Professor E. Führer at the University of Agricultural Sciences, Wien took the initiative and responsibility. The proposal was approved and a concerted action started in 1996 and ended formally in March 1999.

The final results are published in a special issue of Forest Ecology and Management with the title "Pathways to the wise Use of Forests in Europe" (FÜHRER *et al.*, 2000).

DEFINITION OF CONCEPTS

Sustainability. Sustainability has traditionally been seen as the ability to maintain productivity indefinitely with no net decline, even if the forest is subject to stress and perturbations. This might best be termed *Sustainability of Yield*.

More recently, sustainability has been understood as much in terms of the maintenance of a balanced nutrition of the plant cover, maintenance of the soil capacity for future production, maintenance of the hydrological stability of catchments, or the maintenance of other more society-centred values and amenities. In contrast to previous definition, this might be termed *Sustainable Forest Management*.

Resilience. The ability of a system to return to its original state or a new equilibrium after disturbance.

Multifunctionality. The attempt to satisfy simultaneously the economic, social and aesthetic demands we place on the forest resource.

Forest exploitation in Europe: a historic perspective

An historical overview of forest exploitation and development of forestry in Europe has recently been given by FARRELL *et al.* (2000; and literature cited there). From this review we can summarise the following.

The history of the human interaction with the forests in Europe is long and complex. KIMMINS (1992) identifies four different stages in this history: (1) Unregulated exploitation of local forests and clearing for agriculture and grazing; (2) Institution of legal and political mechanisms or religious taboos to regulate exploitation; (3) Development of an ecological approach to silviculture and timber management and the goal of sustainable management of the biological resources of the forest; (4) Social forestry, which recognises the need to manage the forest as a multi-functional resource in response to the diverse demands of modern society.

Stage 1 - 2. The availability of wood was a prerequisite for the expansion and development of all the early civilisations. The search for new woodland to exploit resulted in wars and conquests of adjoining territories. When this no longer proved successful, conservation methods were often attempted, with strict legal penalties or religious taboos placed upon the felling or exploitation of certain species and the grazing of woodland. In Ancient Greece, for instance, sacred groves generally escaped the axe, coming to resemble modern-day national parks as refuges of pristine wilderness. However, by the fifth century BC, when wood shortages had become acute, religious sanctions were no longer enough, and secular punitive measures were taken to protect the groves. On the island of Kos, anyone found cutting down cypress trees was fined the equivalent of three years' pay for an average worker. Laws proliferated into the fourth century B.C. A decree in Athens forbade the removal even of twigs from groves. In this period, Macedonia, with its great resources of unexploited timber, overtook Attica as a great power until it was in turn eclipsed by the rise of Rome.

The serious, direct consequences of deforestation were recognised as long ago as the third millennium BC in Mesopotamia. The droughts that followed the felling of the great cedar forests of the Fertile Crescent are alluded to in the Epic of Gilgamesh. In the fifth century BC, Plato noted the damage to the soil resource resulting from deforestation in Attica. Erosion reduced agricultural productivity, resulting in further forest clearance to make new areas of fertile land available for agriculture. Industries such as iron smelting, pottery and shipbuilding were directly affected by the shortage of wood.

As in the Ancient World, the consequences of deforestation for soil stability and regional hydrology were learned through catastrophe. The concept of forest protection originated in the Middle Ages; in Switzerland the oldest records of protection forests, where all cutting was prohibited to prevent avalanches and landslides, go back to 1339 (Muotathal) and 1387 (Altdorf). Despite the fact that reforestation of felled sites in the vicinity of Nürnberg, in Germany, had been initiated as early as the 14th century by Peter Stromer, hard lessons were still to be learned. Even as late as the 19th century, large-scale clearance of Alpine forests resulted in devastating erosion. Legislation controlling felling at high elevations was introduced watershed management became an important function of the forester in Alpine regions. While the benefits of this strategy soon became apparent, it was also recognised that this control represented an artificial manipulation of a natural system and the need for a more ecological approach was recognised. By the 1950s, various forms of "near-to-nature" forestry were being implemented in mountain regions in Switzerland, France, Germany, Italy and Slovenia.

The strategy of the acquisition of timber supplies through the occupation of new territories, common in the Ancient World, appears again in medieval Europe. As long as forests were apparently limitless in extent, there was no concern to conserve or manage them, but when they became scarce, migration and conquest often began. In Central Europe, around AD 1000-1100, a need for new sources of wood drove the Germans into the lands of the Slavs. Wood shortages in Britain were, in part, responsible for the destruction of Irish forests.

In more recent times, migration has been of less importance and conservation strategies have been employed, but with varying degrees of rigour. While Colbert's ordinance of 1669, which recognised the need to protect the forest and sought to regulate intervention in the forest, is well known, the first forestry code controlling the felling of oak in France, was introduced as early as 1376. At an even earlier stage in Austria, due to intimate connections between mining industries and forestry, regulation of mining included strict rules on the use of mountain forests. For example, in a mining code issued in 1237 by the Archbishop of Salzburg, the transformation of clearcut areas to meadows and pasture was prohibited and reforestation was made mandatory. Around the same time, donations made to monasteries by the Archbishop of Salzburg were accompanied by injunctions against forest clearance.

Stage 3. Few civilisations have ever proceeded beyond Kimmin's second stage in the history of human interaction with the forest, even though some silvicultural techniques were known in the pre-Christian era. An early example of silviculture is to be found in the work of Cato from about 200 BC. In an agricultural treatise, he describes wood as a crop (though of little value) and describes how to coppice, set up willow groves and plant poplar on wet ground. It was his belief that an estate should grow its own timber, so as to import as little as possible. Varro (~30 BC) and Columella (1st century AD) also wrote about silviculture, particularly of elm, since it was useful in training vines and as fodder for sheep and goats. In Egypt, in the third century BC, arboriculture was practised to relieve wood shortages in a land short of indigenous timber. Willows, mulberry trees, acacias and tamarisk were planted in parks, and the government provided nurseries for gardeners to tend their seedlings. However, wood grown in Egypt never attained large size and the Egyptians were forced to construct ships and buildings with imported wood. Much later, in the 11th century AD, when diplomatic strife led to severance of trade between Egypt and its main suppliers of wood, the cultivation of trees became a national priority. Trees were planted on both sides of the Nile, and were irrigated by canals. Over one hundred square kilometres were given to trees in this important agricultural region, indicating how seriously the shortage of wood was being taken. Later still, many monasteries were established on the margins of forests in order to develop the forest resource, establishing intermediate zones between the dense forest and open farmland where coppice systems were practised.
Hence, it seems that the potential to progress to the next stage, the scientific management of forests, existed in several previous civilisations. It is interesting to speculate why these ancient civilisations never made that step towards sustainable forest production. In some cases, conquest opened up new sources of pristine woodland for exploitation and the techniques that had been learned were shelved or forgotten. In others, social decline had proceeded too far to allow the effective implementation of silvicultural strategies. However, perhaps the philosophy of the times was the overriding factor preventing the development of large-scale scientific forest management.
A paradigm shift occurred in the late 18th and early 19th centuries with the establishment German, Austrian and French forestry schools. Man had now an attitude of "manipulating" nature. The importance of site productivity was emphasised as a control for site exploitation. It was also assumed that the site productivity was stable over time. The forest was now a resource to be utilised. We can see how man's appreciation has changed over time (see further FARRELL *et al.*, 2000).
The emergence of scientific forestry did not put an end to the exploitation of forest resources. As populations grew, the demands on the diminishing forest resource increased, the distance to forest resources increased and the supply of both wood and non-wood products from the forest became crucial to the sustainability of the human population. In some cases, unregulated felling continued on a large scale. Practices such as litter-raking developed into established rights over much of Central Europe without any realisation that they might have a detrimental influence on the long-term sustainability of the forest. Openings in the forest were used as pastures; litter was gathered for use as bedding for animals and subsequently, mixed with dung, as an organic fertiliser. In broadleaved woodland, leafy twigs were harvested, dried and used as winter fodder.
Moreover, the paradox of the forest decline phenomenon is that the documented evidence of a deterioration in forest health has been accompanied, in some of the most severely polluted areas of Central Europe, not by a reduction in site productivity as might have been predicted but by increased productivity. The causes of this trend are complex, but have in many cases been related to more sustainable forest use patterns and to climate change. Growth stimulation may result from increased availability of soil nitrogen, both from atmospheric sources and from improved land management practices, interacting with elevated concentrations of carbon dioxide in the atmosphere. However, these growth increases may be short-lived, as little is known yet of the long-term influence of increased availability and accumulation of nitrogen on the sustainability of forest ecosystems. The recovery of damaged forests and the recently confirmed increases in productivity, both of which run contrary to the expectations of only a decade or two ago, are evidence of persisting deficiencies in our understanding of ecosystem function (HÜTTL, 1998).

Stage 4. As discussed previously the scientific approach to the management of forests in Europe has been based upon the maintenance of a sustained yield of wood supply. To day's ideas of sustainability embrace all the goods and services of the forest and suggest that "sustained yield" should be replaced by the broader concept of "sustainable forest management", as defined earlier.
This broader definition of sustainable development puts new demands on the forest manager, expanding the scope of management to embrace a wider range of goods and services. This, in turn, requires that we better understand how the many forest ecosystems of Europe or elsewhere function, so that we can define regional criteria for such sustainable management. This is a challenging task. At best, the practice of ecosystem management is fraught with difficulty. A consideration of the several biomes which the forests of Europe embrace, the highly disturbed, dynamic nature of these ecosystems and the paucity of data on

their properties and stage of degradation or recovery further emphasises the enormity of the task.
In the context of current views on sustainable development and at a time when the dynamic nature of our forest resource is becoming ever more apparent to us, the shortcomings of models that are narrowly focused on yield prediction and based on historical performance become glaringly obvious. The demands of modern society require a new approach, embracing all the functions of the forest. The working assumption underlying current models, that growth will continue in the future according to the patterns established in the past, has been invalidated by the recent studies of growth trends (SPIECKER *et al.*, 1996). Circumstances have changed. The steady state no longer exists, if it ever did. New models are required to simulate not only forest growth, but also the ecosystem processes that contribute to the sustainability of the forest. These models must be based upon ecosystem processes and the environmental factors that drive them. Research on such process-based models is in progress (see MOHREN, BURKHART, 1994; ÅGREN, 1996; ÅGREN, BOSATTA, 1996), but it will be some years before they can be used as management tools. When they are ready for use, another stage in the evolution of scientific forest management will have begun.

FOREST ECOLOGY IN A BROADER SCOPE

In order to develop priorities for future forestry research with an ecological emphasis there are some facts to be considered. Sustainable forest management as defined previously is understood as a multiple use of the forestland in a way where future generations will have at least the same assets as we. In practising this kind of forestry the classical forest stand or forest ecosystem level research is no longer sufficient. The investigation of problems related to biodiversity and water quality as well as those linked to management practices will have to be conducted on a broader scale than previously, a landscape approach is needed.
The balancing of the multiple use of the forest landscape will require an integration of biological/ecological characteristics with socio-economic and socio-cultural ones. Therefore conventional stand-planning needs to be supplemented with landscape-based planning. This will require a close collaboration between planners, managers, ecologists and other specialists for the development of criteria, which are linked to an understanding of the principles and aims of sustainable forest management.
Various management approaches such as multiple-use forestry, sustainable forestry, adaptive management or ecosystem-basis management have been proposed and applied. However, the successful management of forest ecosystems and landscape requires a thorough understanding of the complexity of interactions between forest management, the forest ecosystem and landscape functioning. An integration of ecological, economic and social factors in the planning process is essential.
We are living in a changing environment. Not only are we adapting our management practices in response to economic imperatives and technological development, but the physical and chemical climate is rapidly changing also, as a consequence of our combustion society. Climatic changes are occurring leading to unexpected and also rapid alterations in the environment in which our forests grow. We need to understand these changes and also be able to predict them if we are to adopt appropriate mitigation strategies.
With increasing basic knowledge of the forest ecosystem and the forest landscape, a closer mutual collaboration between stakeholders, planners, managers and scientists from a variety of disciplines will be needed in the future. It is a challenge for the next decade and onwards to develop and foster such collaboration.
Based on the experiences of EFERN, we believe it is essential to contribute to an increased exchange and collaboration between disciplines, in order to give a new direction to forestry research. We suggest therefore the introduction of *ecosystem and landscape forestry* as a theme integrating the various components for developing a sustainable management of forest ecosystems and landscapes.
In the following text ecosystem and landscape forestry - ELF - is outlined as well as priorities of major scientific complexes/questions are presented. Details of research questions of biodiversity, biomass production, and regional aspects are discussed at several places in FÜHRER *et al.* (2000). This paper does not claim to be fully systematic, nor to give a full coverage of all fields. It should be seen as an attempt to bring different disciplines together in an orderly way with the aim of introducing a holistic approach to sustainable forestry.

COMPONENTS OF ECOSYSTEM AND LANDSCAPE FORESTRY: ELF

The major components of ecosystem and landscape forestry are seen in Fig. 1. Planning of forest ecosystems and landscapes is based on criteria - biological, ecological, hydrological, economic and socio-economic - derived from the best causal knowledge. Management is the tool, which brings to reality the aspirations of the planning process. Forest management needs to develop or modify existing techniques and strategies so that a multi-purpose sustainable forestry can be applied. Planning and management practices must vary in scale as well as time depending on several factors, such as ownership, composition of landscape etc.
An understanding of land-use history and previous management are essential to the development of systems for sustainable forest management. The future development of ecosystems and landscapes is dependent not only on the management strategies we adopt, but also on changes in physical and chemical climate or air pollution and climate change.

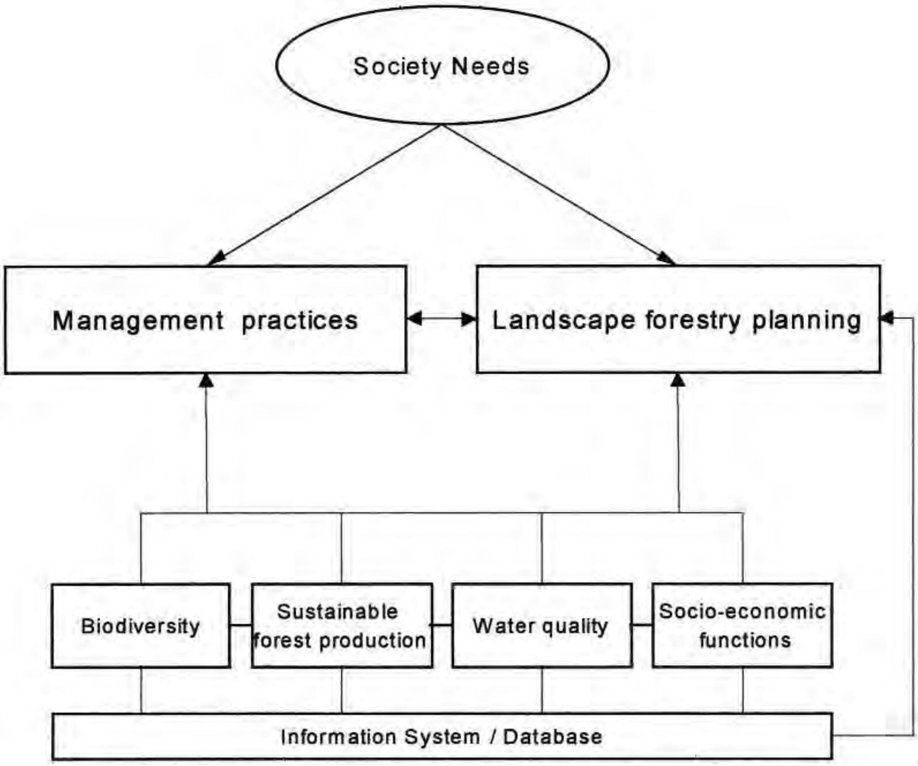

Fig. 1
Major components of ecosystem and landscape forestry aiming at sustainable forest management.
Componenti principali degli ecosistemi e del paesaggio forestale nella gestione sostenibile delle foreste.

RESEARCH AND DEVELOPMENT PRIORITIES

In a number of chapters in FÜHRER *et al.* (2000) and ANDERSSON *et al.* (2000a) forestry problems and future research topics related to sustainability are analysed.

Landscape-based forestry planning: balancing multiple interests. The concept of "sustainable forest management" encompasses several criteria, which may be used as guidance when managing the forests and the landscape. The planning process in this context is a balancing act, where different, sometimes contradictory, possible uses or values are dealt with or considered. These values and their relative importance vary over time and between different societies or countries. Therefore landscape-based forestry planning is a dynamic process for generating decision support for the balancing of the different dimensions out of the prevailing set of values and out of the present knowledge (CARLSSON, 1998).

In order to generate a decision support it is essential to have a multidimensional description of the forest on a region/landscape level. This description needs to include the different components of the system as a basis for the evaluation of different criteria. Furthermore analytical tools for handling the balance of different alternatives are needed. In order to make the whole process transparent to stakeholders and others an improved knowledge about the societal values assigned to different dimensions of the forest is needed, as well as an improved knowledge of the effects and consequences in the ecosystems of different human actions. This means that this planning component of the programme, to some extent, would perform the role of linking together results and knowledge generated in other parts of the programme.

Carrying out research in this area on a European scale means dealing with great regional diversity in ecosystem character and social systems, forest history and, ownership structure. This diversity increases the complexity of an integrated research effort.

Management practices. A basic principle of forest management is to focus on the protection, maintenance and/or restoration of the structure and functioning of the natural processes of forest ecosystems and its components at all landscape and time scales. Multi-functionality and aesthetics are self-evident constituents. Good management is founded on both the needs of society and the objectives of the forest owner.

By generating knowledge on the consequences of changes in land-use as well as on the influence of atmospheric and climatic changes on forest ecosystem health and productivity, a scientific basis for innovative forestry practice is at hand. Forest managers need therefore to intensify their analyses of forest health or vitality, enhance the use of predictive models, and make more frequently use of risk assessments.

The availability of long-term data significantly improves our understanding of the changes in the forest, it's functioning and its potential behaviour under changing environmental conditions and the resulting risks. Knowing more about the effects of natural disturbances and forest management activities will ensure that our national and international policy debates are rooted in science. The challenge will also be to find ways to measure and monitor global environmental changes in European forest ecosystems with a view to shaping and sustaining forest ecosystems and landscapes.
For environmental resource managers, uncertainties are unavoidable because of natural ecological variability and our imperfect knowledge of ecosystems. In order to make political and management decisions, risk analysis becomes an important tool for forest/landscape management because it accounts for the uncertainty about states of nature. The assessment of risk associated with different management methods is essential in all regions. As an example the risks associated with mountain environments are growing rapidly with increasing resident and visiting populations, intensification and diversification of land uses, and the construction of infrastructure. Consequently, risk assessment and risk management are of great importance and call for an ecological basis to decision making in a world of uncertainty.
Biodiversity. The structures and components of the forests are different in different parts of Europe. However, key factors in the landscape determining biodiversity are structural components of the forests, such as dead wood, e.g. dead standing trees, snags, down logs, etc. Old trees, multi-layer canopy structure, uneven age structure as well as tree species composition, are other structures of importance, not least for the many species with specialised habitat needs.
There are some disturbance regimes, which are similar and common to the whole the European continent. Fire as a disturbance process has been or is of importance both in the boreal parts of Europe and in the Mediterranean region. Another disturbance process of importance is the effect of grazing and browsing animals. This process is also quite evident both in the southern and northern part of the continent, although the herbivores influencing the vegetation are different, and the ecological effects are different. Another feature common to most of Europe, which certainly will influence biodiversity, at least at stand level, is the use of exotic tree species.
Planning, in a landscape perspective, will influence the possibility to maintain species dependent on patches or specific ecosystems in the landscape in such densities that the distance between suitable habitats will be shorter than the dispersal capacities of the species involved.
The management of forests must be carried out in the context of the whole landscape. However, management in the landscape perspective will take into account matters such as stand size, distance between forest units, an appropriate mix of different ecosystems. Nevertheless, management at stand level cannot be neglected, as it is essential for the sustainability of forest ecosystems and the maintenance of long-term biodiversity. Development of management plans including information about for example, key structures of importance for biodiversity in different types of forests should be possible.
Maintained or improved biodiversity of forests is a part of sustainable production. If this is accepted, there will be a connection between sustainable production and the socio-economic functions of a region. The reason is that maintained or even increased biodiversity will be a part of the attraction of a landscape.
Biodiversity is also connected to water quality, which to a great extent is influenced by forest management activities The way foresters treat water in the forest by for example ditching, will also influence the biodiversity in riverine forests along streams of different size.
However, there is also a connection between biodiversity and socio-economic functions in the other direction. As indicated, maintaining biodiversity in the landscape or province is certainly a value, which will be regarded as a part of the socio-economic functions of importance in the future. The tourist industry based on eco-tourism will be much a function of the landscapes and regions where the biodiversity of fauna and flora will be managed in a sustainable way.
Sustainable tree biomass production. The ability of the forest to produce energy, fibre and timber as well as other commodities is fundamental to man's existence (FARRELL *et al*., 2000; PIUSSI, FARRELL, 2000). This ability must be used and managed in such a way as to ensure the maintenance of sustainability. Our understanding of forest production and forest growth and thus sustainability is incomplete (ANDERSSON *et al*., 2000 b). Present yield tables do not mirror today's growth levels in boreal and temperate regions of Europe. It is argued that we need a causal understanding founded upon a mechanistic knowledge of important processes.
For planning purposes there is a need to predict the effects of management strategies as well as different environmental changes. An increased understanding of plant/soil relationships as well as a better understanding of the biological part of the soil system is required. The spatial resolution in present soil sampling for chemical analyses may not be fully relevant in describing plant/soil relationships. It has been shown that the near-root environment deviates from the conditions described by bilk chemistry.
Sustainability of forest production is usually discussed from a long-term perspective. Long-term changes can lead to deficiency or even excess of mineral nutrients, which will affect the resistance of the tree or stand to frost and attacks of insects and pathogens. Recent advances in the understanding of tree vigour or vitality in relation to insects and pathogens are reviewed as a component for understanding production stability in short- and long-term perspectives.
Water quality. In many regions in Europe water resources in forests have become increasingly important to guarantee a drinking water supply. As a con-

sequence, sustainable forest management must also integrate the various ecological and socio-economic benefits resulting from water resources.
Water is of course an important factor for forest growth. In this connection the importance of the vegetation cover in stabilising nutrient retention in the ecosystem as well as preventing erosion also calls for further attention. Likewise the importance of fire needs to be considered.
A multi-functional and sustainable forest management system should adequately consider the protection, maintenance and - where necessary - the restoration of water resources and aquatic ecosystems. However, conservation of water quality represents a highly integrative effort encompassing various temporal and spatial scales of forests as components of landscapes. Water-related questions in forests inherently need to be addressed on the catchment scale. Nevertheless, the hydrological catchment approach has to be combined with the traditional stand-based nutrient cycling approach in order to obtain a reinforced understanding of underlying processes. Beside the study of interactions of water on its way through various types of forested catchments an experimental approach is essential. Short-term forestry operations (harvesting, thinning, road construction, (fertilisation/liming) have to be studied in model catchments as well as effects of changed silvicultural concepts (e.g. conversion of conifer plantations into age-structured mixed stands) on various time scales. Long-term silvicultural manipulation experiments on the catchment scale appear to be essential in order to generate controlled side-conditions for a successful interdisciplinary research. Modelling of water and element fluxes be developed further as a valuable tool to link processes on various temporal and spatial scales in catchments.
Socio-economic aspects. The multi-functionality of the forests implies that there are a number of interested parties involved, with different demands upon the forests. A most important link in applying sustainable forest management is therefore that the socio-economic aspects are considered and included in planning.
The overall question for the socio-economic analyses will be: how to combine or "balance" different forest functions (or goods or uses) so that their joint contribution to the regional welfare is as large as possible? Answering this question requires research in several fields:
Analyses of external effects. An external effect is at hand when one use of forest ecosystems/landscapes influences, either negatively, or positively, the possibilities for another use. For example, both forest management practices and recreational activities may negatively affect biodiversity. On the other hand, there are positive external effects, e.g. when roads, built primarily for forestry activities are also used by recreationists for reaching remote areas. Negative as well as positive external effects can easily be seen in the forest. However, there is a lot of research to be done on analysing and measuring these effects, in a way that helps answer the overall question.
Estimation of values of different goods (or uses or functions). While timber is priced on the timber market, and its value is thus known, other forest goods have no market prices that adequately reflect their values. For example, The Right of Common Access in Nordic countries (or Switzerland) means that forest environments for many recreation activities attract no market price – even though they may have high recreation values. This is true also for forest landscape scenarios, which can be enjoyed even without any Right of Common Access. Furthermore, there are existence values associated with fauna and flora species. Such existence values are indicated by, among other things, the fact that many people are willing to pay money for saving endangered species. Without research aimed at value estimation of non-market-priced goods, and thereby making them more comparable to timber revenues, it is difficult to consider them properly in forest management programmes. The number and quality of goods that the forests provide is, to a large extent, dependent on forest management practices. It is, thus, important to undertake research on different forest management practices with regard to their effects on environmental values.
Estimation of costs of environmental considerations. Research on how different forest management practices affect environmental values must be combined with research on the effects on forestry efficiency. Adaptations in forest management practices that increase the environmental value of the forests often involve costs for forestry in terms of, for example, lower timber volumes, more expensive cutting methods, etc. Furthermore, there may be costs associated with, for example, limiting recreational access to forest areas devoted to biodiversity. In reality, there are many "types" of costs associated with alterations in the use of forests. It is important to know more about these costs and to measure them in a way that reflects their true value.
Research within the sub-fields touched upon above can contribute to the development of forest policies and forest management practices that can balance different forest functions efficiently, which is, in turn, important for regional development in large parts of Europe. It is also clear that the research must have an interdisciplinary approach. Economists must work together with other social scientists (e.g. sociologists) as well as with natural scientists (e.g. ecologists and silviculturalists). Smart solutions require better co-operation!

Research and development priorities

In order to apply sustainable forest management according to the principles of "Ecosystem and landscape forestry" on a European scale we can characterise the focal areas for research and development as follow:
Planning: to generate decision support for the balancing of the different dimensions of sustainable forestry. This support should take into account dif-

ferences between ecosystems and their uses as well as social systems found on a European scale.

Forest management: to develop management strategies for self-sustaining (productive) forest ecosystems based on ecological knowledge of thresholds and disturbance regimes. We need to develop management strategies, which satisfy the needs of the society without jeopardising the integrity and ecological stability of ecosystems and landscapes.

Biodiversity: to contribute to the understanding of the development of biodiversity patterns in different European landscape types, especially including the effects of socio-economic development and patterns in the landscapes studied.

Sustainability: to develop mechanistic understanding of forest growth/production based on research directed towards causal relationships of plant/soil and plant/pest organisms including climate, nutrients and water, especially considering long-term aspects.

Water quality: to develop a relevant understanding of how forest management affects water quality and plant growth for different purposes according to the need of the society.

Socio-economics: to combine or balance different forest functions (goods or uses) so their joint contribution to the regional welfare is as large as possible.

CONCLUSION

Sustainable forest management requires an adequate understanding not only of the forest ecosystem but also other disciplines and their interaction. The planning process and finding the appropriate balance of different interests for the use of our forests and landscape resources will be vital to the achievements of the goal of sustainable forest management. The interaction with the Society and its norms will encourage scientists to develop criteria or standards to be met. An increased interaction between disciplines is expected, which will influence not only research but also education at different levels. *Ecosystem and landscape forestry* will be a key topic for the introductory decade of the new millennium.

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RIASSUNTO - L'EFERN (European Forest Ecosystem Research Network) è stata costituita nel 1996 a seguito delle conferenze ministeriali *Protection of European Forests* svolte a Strasburgo nel 1990 ed a Helsinki nel 1993 con lo scopo di promuovere la ricerca indirizzata alla gestione sostenibile delle foreste e di fissare le priorità per le future ricerche nel campo dell'ecologia forestale. Accettando l'idea che il concetto di sostenibilità delle foreste include un approccio multifunzionale, si evince la necessità di integrare le ricerche dell'ecologia forestale classica con quelle sulla biodiversità, sulla qualità dell'acqua e sulle condizioni socio-economiche. Attraverso la pianificazione si possono equilibrare i diversi interessi nel campo forestale. Da ciò deriva anche la scelta dei metodi di gestione adeguata delle risorse forestali. A tal fine, c'è oggi bisogno, a fianco alla scala a livello di bosco, di una scala aggiuntiva nella ricerca forestale: quella a livello di paesaggio. Lo scopo di questo lavoro è di presentare un modello concettuale che integra le discipline coinvolte nell'ecologia degli ecosistemi e del paesaggio e dei loro componenti. Si riportano infine le aree che si ritiene centrali nel lavoro di ricerca e di sviluppo.

AUTHOR

Folke O Andersson, Department of Ecology and Environmental Research, Swedish University of Agricultural Sciences, PO Box 7072, S-750 07 Uppsala, Sweden

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From multiple-use management to ecosystem management in forestry

Y.C. YANG

ABSTRACT - Early forest management concentrated on the practice of normalizing forest stockings in time and space. Sustainable yields are made possible by means of scheduling harvest, and by adjusting growth and yield components of the forest, such as thinning and restocking. Later in the 60s, the principle of multiple-use came into the mainstream. In addition to forest products, other use of the forest that included the watershed, wildlife, and recreation were also promoted. Forest is not only a provider of wood and other materials, but it is also a contributor to environmental protection, aesthetic accommodation, wildlife preservation, and social-cultural amplification. This paper explains the new paradigm of forest ecosystem management in the light of ensuring sustainable supply of forest products and services, as demanded by the society and by the changing of global functionality and stability of the ecosystem.

Key words: ecosystem management, environment conservation, forest management

INTRODUCTION

Foresters are interested in forest management because the forest provides products and services for people. There are two kinds of contributions given by the forest trees. One is by means of wood production, which may be called direct contribution; the other is by means of environmental service, which may be called indirect contribution. Direct contribution comes from cutting trees and indirect contribution is from living trees, they are mutually exclusive. Wood production is mainly for private profit making, and environmental service is for public interest. Thus, direct contribution benefits a few and indirect contribution affects many. Conflicts between the two are inevitable.

Recently, human dimension in forestry has been enlarged. Negotiation and compromise among conflict interests have become the new role of forest management. Foresters must adjust to these changes and consider the need of the general public. Some foresters revitalize old doctrines such as multiple-use, resource conservation, and sustainable yield, while others advocate new phases such as multi-resource management, sustainable development, new perspective in forestry, and ecosystem management. We are drawn into a modern paradigm of forest management.

The objective of this paper is to study the historical forest management practice in Taiwan. The paper will cover the classical timber management, earlier multiple-use management, and the latest ecosystem management. The practices adapted to the mandate changes at different eras were also discussed. By re-examining the evolution of forest management practice in Taiwan, we may gain sufficient insight to face the new challenges of the future forests.

THE THEORIES OF FOREST MANAGEMENT

Ever since the first Forestry University was created by German foresters H. Cotta, G. L. Hartig and J. C. Hunderhargen, practice of forestry has been a science and a profession. The primary goal of classical forest management was in timber production. Management was influenced by the mercantile theory that was formulated in Germany around 1800. Prior to 1960, wood production has been the major use of the forest. During this period, Earth Rental (Bodenreinertragstheorie) representing the net return to the land, and, Forest-Rental (Waldreinertragstheorie) representing the net return to the forest, were the two principles of forest management. According to the principle of net return to the land, forest is used as an object to earn money for the land. Therefore, moneymaking and profit making would force foresters to clear-cut all hardwood forests and replace them with softwood plantation. On the other hand, the principle of net return to the forest advocates the beneficial contributions of forest to the physical and mental health, as well as to the cultural enhancement. Therefore, foresters should practice selective cutting and create mix-stands.

In 1960, a world congress of the International Union of Forestry Research Organization (IUFRO) was convened in the United States. The overemphasis of timber production, and the traditional paradigm of maximizing the sustainable yield of wood were criticized and re-examined. Multiple-use forest management was proposed as the core of this symposium because the general public at that time had generated great expectation of the forest. Multiple-use involves timber, watershed, forage, wildlife, recreation and esthetics. There was nothing new about the use of the forest, but it was a new consideration for all users of the forest that equal weight is given to multiple-use rather than just to timber production.

Environmental impacts due to multiple-use of the forest caused a philosophical self-examination. Recently, Forest Ecosystem Management has been proposed. The origin can be traced back to the idea " Back to Nature" of a German forester K. Gayer (HESKE, 1938). Actually, the Chinese view of nature is very close to Gayer's doctrine and German philosopher I. Kant's saying "The people stand in awe of nature". From the beginning, China has been an agricultural (including forestry) country. The livelihood of the people cannot be separated from land and forest. The sayings "To bring out the greatest productivity of land" and "Forest management should not be in contradiction of the proper time" demonstrate the naturalism of the Chinese people. Naturalism leads to the development of ecological ethics. The ecological ethics is to study the ethical, moral relationship between mankind and nature, and apply the moral means and legal, economical and administrative measures to put an end to the ecological distress, so that mankind and nature as a whole may progress in co-evolution (YEH, 1995).

Following the teaching of Dr. Sun Yat-sen that "The natural resources of a country are the property of the people, highest yield of goods to the greatest number of people should be made possible, "the forest management in Taiwan has its goal for long-range land conservation to stop exploitation of the forest for financial gain. At present, the ethical paradigm of a forester is "to serve society" and "to serve forest".

TRADITIONAL FOREST MANAGEMENT

Forest is of great importance to Taiwan, because forest covers more than half of the land. The forest not only provides forest products for her people, but also protects their watershed. The ragged topography, steep slope, easily erosive soil, and abundant rainfall, frequent typhoon seasons demand forest cover for soil conservation and flood damage.

Soil and climate in Taiwan are conducive to rapid forest growth and development. The wide range of climate and topographic conditions on the island has resulted in several major forest types. Coniferous forests predominate on the high elevations. Mixed forests of conifers and hardwood occupy relatively few areas. Hardwood forests are distributed from sea level to about 2,000 m in southern mountain areas. Bamboo covers primarily tropical and subtropical zones.

Because the time requirement for a tree to reach maturity is long, a long-term management plan should be prepared. Furthermore, trees are more like money than other agricultural products, that the growing stock (capital) and growth (interest) are the same materials, not clearly distinguishable; they are tied together. Therefore, a long-term plan should take considerations of the management objective, present forest condition, location and regional economic situations.

Based on such considerations, the important forests in Taiwan were subdivided into 40 working circles. Each working circle was further subdivided into compartments, and sub-compartment according to soil site, species composition, stand structure and operational organization.

From 1925 to 1943, a management plan was prepared for each of the 40 working circles. The German method of regulating the forest, equivalent to a combination of area and volume control, was adopted. In preparation of a management plan, compartments and sub-compartments were outlined, basic information was collected, and management objectives were defined. All activities during the management period were spelled out in details. Attentions were paid to items such as timber harvesting and reforestation, thinning and stand improvement, administration and protection of the forest, maintenance of boundaries, accessibility and transportation networks, supply and demand of forest products as related to other industries, local labor market and livelihood of the people, watershed protection and public interests. The management plans stipulated guidelines for scheduling tasks and for executing forest activities. Revision of the plan was done once every ten years to check the progress in place and the results achieved, so that a new plan for the future could be formulated.

After 1960, multiple-use management plan was proposed. Forest was not considered only as producer of wood and materials, but also as contributor to environmental protection, wildlife preservation, aesthetic accommodation, and social-cultural amplification. Management plans were not limited to the 40 working circles, the Bureau of Forestry and the forestry district were looking at a wider areas and deeper insight to the areas they covered.

Recently, ecosystem management is advocated. Men are not just the users of the forest, but also the servers of the forest. We must obey natural rules and ecological principles, making each component of the forest, tree herb, animal, soil and water interdependent and interactive with each other, so that a sustainable balanced succession may evolve.

FOREST MANAGEMENT AND ENVIRONMENT CONSERVATION

Forest trees are the prevailing vegetation that proliferate continuously on the surface of the earth. About 3% of the total land area is covered with trees, and about 90% of the total biomass is produced by the forest. Global carbon fixation is maintained mainly in the large volume of growing stock. Therefore, contribution of forest to the environment can be compared, and may even surpass the contribution to forest products. However, the shrinking of the tropical rain forest, the swelling of wasted lands, and the distancing of mankind from the forest had startled the general public to contemplate forest as an environmental wealth, and to put forestry in a new place of social framework. Hence, the science of Forest Environment Valuation was born (KITAO, 1995), and a treaty to restrain cutting, protect biodiversity, and emphasize positive forestry operation was signed by the United Nations Conference on Environment and Development.

Promoting healthy forest practice has become the main theme of the Global Forest Convention. Other international agreements, such as "Climate Change Treaty" and "Species Diversity and Forest Principles", are also closely related to forest management. These treaties may regulate future management practice, because forest is the largest land ecosystem, any regional changes in forest yield and forest biodiversity will also change the global climate. With environmental conservation in mind, the "Regulation of Taiwan Forest Management" was published (RU, 1990). The first article points out directly that "Taiwan forestry adopts the principle of sustainable management, with mission to benefit the livelihood of the people, to secure forest resources, to ensure land protection, and to promote soil and water conservation." The 8th article stipulates, "The amount of annual cutting of all Taiwan forests is limited to fifty thousand cubic meters. Every cutting area is limited to five hectares. Cutting is prohibited in natural Taiwan cypress forests, or forests on watershed and reservoir, on ecological conservation areas and areas which are difficult for reforestation." These articles acknowledge the importance of public interests in multiple forest functions.

To manage a forest under the scheme of multiple functions, the whole forest should be divided into several districts according to their major function. The priority order of function among Taiwan forest districts is as follows:

(1) Land protection, including soil and water conservation, watershed protection.

(2) Nature conservation, including ecological area conservation and natural reserves.

(3) Forest space use, including recreation, culture preservation and environment improvement.

(4) Wood production, including timber and by products of the forest.

It can be seen that environment conservation has become the central theme in forest management. The wood production function in Taiwan has been reduced greatly in the recent years.

FOREST ECOSYSTEM MANAGEMENT

Forest management used to be the application of business method and professional forestry knowledge to the operation of forest property as related to human needs. The forest as a whole is managed to produce various benefits to mankind. However, the recent demand for timber and forest related products increased with economic growth and development, at the same time the general public raised concerns about nature conservation. This tug of war has made the old methods of forest management obsolete. Now the problem of managing a forest becomes complex and uncertain. The manager needs to respond to the diversified nature of the forest itself, as well as the different biological, physical, and economic processes inside and outside the forest. In view of the inherent complexity of the forest management problem, the traditional method needs to be replaced by the forest ecosystem management.

The scope of forest ecosystem management is large, two of the most meaningful definitions are cited below:

(1) Forest ecosystem management is a resource management system designed to maintain or enhance ecosystem health and productivity while producing essential commodities and other values to meet human needs and desires within limits of socially, biological, and economically acceptable risk (SOCIETY OF AMERICAN FORESTERS, 1993).

(2) Ecosystem management is management driven by explicit goals, executed by policies, protocols, and practices, and made adaptable by monitoring and research based on our best understanding of the ecological interactions and processes to sustain ecosystem structure and function (FRANKLIN, 1997).

In other words, the forest resource should deliver more goods and services while maintaining species diversity and collaborate soil productivity (OLIVER, 1993). Forest managers should be concerned about the conservation of biological diversity, the sustainable use of its components and the fair and equitable sharing of the benefits arising out of the utilization of genetic resources (WCED, 1987). The modern forest management should emphasize sustainable development that satisfies the present needs and not damage the capability of requirement for future generation (BUNDTLAND, 1987).

The advantages of forest ecosystem management can utilize solar energy fully and make the forest community healthy to give a stable output. A well stocked forest with well developed canopy can recycle soil nutrients between trees and soil, the physical and chemical properties of forest soil can remain in a stable and equilibrium state.

In reality, implementation of forest ecosystem management requires certain human efforts. In constructing mixed forest with various species, different acceptable silvicultural treatments suitable for specific conditions are recommended to the forestry development in Taiwan. We want to see the practice of this good management method: men harmonizing and helping nature.

It is also desirable to adopt "Trial and error" method in the implementation of ecosystem management. It is simply "give it a try and see if that would work", a repeated procedure to amend the failure until the expected results are obtained. If we do not put ecosystem management in practice, the effectiveness of this new management will never be realized.

PARTICIPATORY IN FOREST MANAGEMENT

The fundamental timber management as related to tree growth and space allocation has not been changed much with the passing century. However, the scope, the logic and the dominant policy of forest management have been steadily evolved throughout the years. Since 1960, forest management has been significantly reformed to include the human dimension. The concept of "Society Forestry" was proposed so that "forestry is not only to study trees, but the problem of mankind is also concerned" (WU, 1999). Forest is not just a production tool for the sole owner, but it is common property owned by all people (SHANNON, 1992). The general public had become more and more interested in how foresters managed their forests (DAVIS, JOHNSON, 1987).

With the rise of environmentalism in the 70's, forestry has been chosen as the representative of nature, forestry problems were openly discussed in the natural resources protection campaign. The public became suspicious of the practice of traditional forest management. Environmentalists had raised their voices against clear cutting in larger area, building more logging road, and assigning more recreation forests. Because many intangible contributions of the multiple-use management are not reflected in financial transaction, the public also questioned whether the conflicts between management goals and user benefits could be reconciled (ZHENG, 1998). General public, environmentalists, and congressional representatives often challenge the professional judgments of forest managers.

Today, the awareness of human rights has been amplified greatly by the mass media. Forest is not only a local issue about timber, rather, it is a global environment resource. Therefore, forest practices subsequently have interested many citizens; they want to ensure that this renewable resource can continuously supply all kinds of welfare. The public wants to understand and evaluate the stipulation of a forest manager. On the other hand, today foresters start to recognize that important choice of forest management decisions is not simply based on technology, the best way is to involve more people directly into the decision-making process. BEHAN (1988) advocated "Constituency-Based Management" because a successful management decision must be based on professional technologies that are workable and beneficial, as well as on public interests and society demands.

Multiple uses and services call for more experts working together to solve forestry problems. Each expert may have different thoughts, and each one may have individual speciality and interest. A participatory approach is an essential mechanism for the protection of the public interest. When it becomes necessary to make an inevitable trade-off, a common denominator must be found among various interest groups. All parties should be incorporated into the decision-making process.

Traditionally, foresters were trained mostly in the biological and physical sciences. We suggest that all forest agencies should train themselves to become more effective interpreters so that they could be well equipped to explain what is the forest contribution to the society and what is the duty of the general public to support and protect the forest. The new forest manager should establish attractive bulletin boards in the corridors of their office building, or in the visible areas of the office to brief the public about their jobs. Video presentation is another effective public media.

Finally, the most important task facing the forest manager is to arouse public attention. He needs to let people become aware of the many contributions of the forest. He needs to mobilize the public interest groups and volunteer organizations to love and protect forest resources.

CONCLUSIONS

In the early beginning of forestry, management practices are based on an idealistic "Normal Forest." Harvests are regulated according to the growth and yield of the forest under certain constraints. The goal is to maintain a desirable growing stock adaptable to the site. Later, under the guidelines of multiple use management, forest is regarded not only as producer of timber but also service provider for environmental protection, soil and water conservation, recreation. Forest is also a place for cultural and education.

Recently, ecosystem management and biodiversity are coming into the main stream. Given forest as a complicated ecosystem, containing abundant species diversity and genetic diversity, it should be able to maintain a living ecosystem. It should provide soil protection, nutrients recycling, water resource stabilization, and climate moderation. A well-managed forest should produce industrial materials, medical supplies, and foods for economy and health. The new forest should become a niche for human existence, a welfare center for scientific, educational, social and cultural activity.

In order to manage such a complicated ecosystem forest, we must obey natural rules and maintain biodiversity, making men not just the users of the forest, but also the servers of the forest. Hence, a harmonious and stable relationship between society and forest may be effectively organized. Since a management plan is essentially a scheme of management aimed at controlling forest activities, which are to carry out a present forest policy, it requires forest managers who understand the plan and in turn execute it faithfully. Otherwise, an unachievable management plan is nothing but a proposal in the front office. Although there are many discussion papers on ecosystem management in Taiwan, few experiments or demonstrations have been made. Therefore, it is necessary for foresters to wake up and work together. This is the time to call for a new paradigm of forest management. We need to break through the traditional single-use German model of timber management, and the forty-year old sustain-yield, multiple-use model, so that we may follow the ecosystem principles to manage the forest to ensure an integrating and continuing flow of products and services from forest to society. The forester should see the forest and not the trees so that he may manage the forest in harmony with natural processes. We hope the result of this research may provide guidance for managing the forest resources in Taiwan as well as in other areas in the world.

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RIASSUNTO - Le prime pratiche di gestione forestale erano basate su pratiche di normalizzazione delle provvigioni forestali nel tempo e nello spazio. La sostenibilità produttiva era ottenuta attraverso la pianificazione dei tagli e regolando la crescita ed il taglio delle diverse componenti delle foreste, come il diradamento e il reimpianto. Successivamente, negli anni sessanta, il principio del multi uso divenne comune ed oltre alla produzione forestale ne furono promossi altri usi, che riguardano l'idrologia, la biodiversità e gli aspetti ricreazionali. Le foresta non è solo un sistema che produce legno ed altri materiali, me è un sistema che contribuisce alla protezione ambientale, alla difesa della flora e della fauna ed ha anche importanti ricadute sociali, estetiche, socio-culturali. Questo lavoro spiega i nuovi paradigmi della gestione degli ecosistemi forestali alla luce della necessità di assicurare la produzione sostenibile dei beni e dei servizi forestali, così come richiesto dalla società e dai cambiamenti delle funzioni globali e della stabilità degli ecosistemi.

AUTHOR

Yong-Chi Yang, Department of Forest, Taiwan University, No.4-2, Sublane 1, Lane 3, Chouchow Street, Taipei, Taiwan

Forest ecosystem management and ecological forest pest management

Z. ZHANG

ABSTRACT - The sustainable forestry development is the strategy and guideline of forestry development in the 21^{st} century. The main approach of forestry study is the forest ecosystem management. Ecological forest pest management (EPM) embodies the theory and methods of forest ecosystem management. EPM developed from integrated pest management (IPM). EPM uses many elements of IPM but it is based on keeping and supporting the natural stability of the ecosystem and suppressing pest outbreaks at the very beginning when the population density is still low. With a special system of collection and processing of information (frequency detection and estimation of pest, predator and parasite population density), biological control decision making is made according to a threshold when pest is slipping away from the control of the natural enemies. EPM can be cheaper than IPM because both costly uses of chemical pesticides and mass inundation by artificially reared parasites or predators are rejected. However, at the present level of knowledge and technology, EPM cannot be elaborated thoroughly.

Key words: ecological pest management, forest ecosystem management, integrated pest management, sustainable pest management

INTRODUCTION

As a developing country with a large population, China has suffered from limited forest resources and many environment problems. There are only 134 million ha. of forest with the coverage rate of 13.92%. To solve the problem, Chinese government has made efforts to develop plantations in recent years. China has now become the largest country in the world in the plantation area with about 33 million ha. in 1990s. Because of the low resistant abilities of large area of planted pure stands to pests and irrational controls, the damaged area increased year by year from 1 million ha. in 1950s to 11 million ha. The pest management of forest pests is essential for the protection of forest resources and environment (DENG, 1998).

FOREST ECOSYSTEM MANAGEMENT AND FOREST HEALTH PROTECTION

Ecosystem management is the integration of ecology, economic and social principles to manage biological and physical systems in a manner that safeguards the ecological sustainability, natural diversity and productivity of the landscape (WOOD, 1994; GRUMBINE, 1994). Forest health protection is an important part of the forest ecosystem management.
The high risk of forest insect pest and disease epidemics is due to the stand density, structure, species composition which are outside the historical range of variability (GRUMBINE, 1994). To implement the ecosystem management in forest health protection, ecological pest management is needed (MORELAN *et al.*, 1994).

LIMITATION OF INTEGRATED PEST MANAGEMENT

Since the concept of IPM was accepted and put into practice, it has made a great contribution to the promotion of pest control, improvement of control efficiency, reduction of control costs, and decrease of the pollution to environment. In general, it has heightened the over roll control level and its rationality. As it is developing in the theory and practice, the limitations are shown as the following aspects.
Ongoing IPM is more like a integrated pest control than a integrated pest management. The emphasis is made on the control after the occurrence but not on the prevention and regulation ability of the ecosystem.
The economic threshold is reached when the outbreak has already begun. The processes leading to the outbreak development are not usually taken into account. As it was pointed out by TSHERNYSHEV (1995). IPM extinguishes a fire rather than the first spark.
The tactics of IPM are adopted to decrease the pest population density without the consideration of the long term impacts on the stability of the ecosystem.

In some place the control tactics have to be used year by year due to the irrational control methods. Some biological agents are used as 'living pesticides'. Mass 'inundation' is dangerous for the ecosystem stability and is undesirable (TSHERNYSHEV, 1995).

CONCEPT OF ECOLOGICAL PEST MANAGEMENT (EPM)

Because of above limitation of IPM and the need for sustainable pest management, EPM was put forward (TSHERNYSHEV, 1995).
Natural ecosystem is self-regulating with high biodiversity and all its components are perfectly balanced (GRUMBINE, 1994), hence large area outbreaks of pests are unlikely to occur. On the other hand, in the agro- ecosystems or man-made forests the biodiversity is low with resulting frequent outbreaks of pests. Long term over use of pesticides further reduce the biodiversity of the ecosystems. Enhancing the self-regulating capacity of ecosystems is of vital importance to suppress the pests. The fundamental way to reduce the loss of the pests in the long term is to improve the structure of the ecosystem through cultural techniques. There have been a lot of successful examples, e.g., control the pine caterpillars (*Dendrolimu punctatus, D. tabulaeformis*) through mountain closure (PENG *et al.*, 1986; ZHOU *et al.*, 1987; GAO *et al.*, 1992a, b; ZHOU, 1993), the apple orchard pest management by means of vegetation diversification and the cover cropping system in Beijing (YAN *et al.*, 1997). The main elements of the EPM are as follows:
- The emphasis on the prevention and regulation ability of the ecosystem.
- A special system of collection and processing of information and frequent detection and estimation of pest and natural enemies.
- The economic threshold is the point when the ecosystem is going to be out of balance.
- The use of natural enemies as regulators of the system. Large scale mass release is not used.
- No chemical is used.

PROCEDURE OF EPM

The management objective is a system which can be a field, an orchard, a piece of forest, or an agro-forest ecosystem and the size is determined according to the management goal. For the sustainable pest management, keeping the long term stability of the system is vitally important. At the very beginning of the system establishment, a stable structure should be made. After that, continual monitoring and maintenance are carried out to enhance the system stability so as to reduce the pest outbreak possibility. Once a pest slips away from the natural control of the system under the favorable environment condition and out breaks, control tactics must be put into use which should not reduce the diversity and stability of the system. The procedure is shown in Fig. 1.

Monitoring system of EPM

There must be an evaluating system in EPM which can predict the possibility of the pest outbreaks. The following indexes are included in the system 1) biodiversity index, through the diversity of arthropods or vegetation pest out break tendency can be predicted; 2) population dynamic index, which includes population fluctuation speed and extent; 3) natural enemy index, such as species, abundance of natural enemies and type of density independency; 4) host index, different host species, varieties, clones have different resistant levels. All these indexes should be taken into consideration, but for a certain system emphasis can be put on some or one of them.

Monitoring method

Monitoring and prediction system of EPM is shown in Fig. 2. First decide the monitoring object that is the important pest species in a given region. Then choose the suitable monitoring indexes and monitoring methods according to monitoring species, technology, economic and social conditions. After implementation of the monitoring a computer micro-soft program is needed to analyze the monitoring results and give out prediction of the system stability.

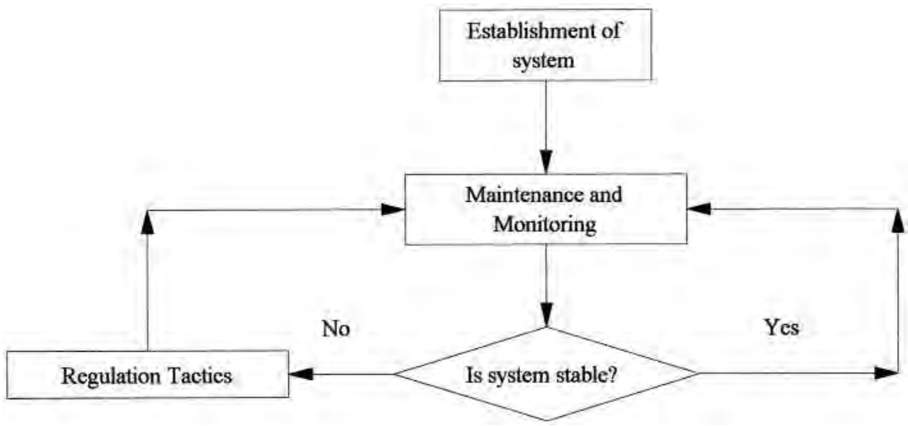

Fig. 1
Procedure of EPM.
Procedura dell'EPM.

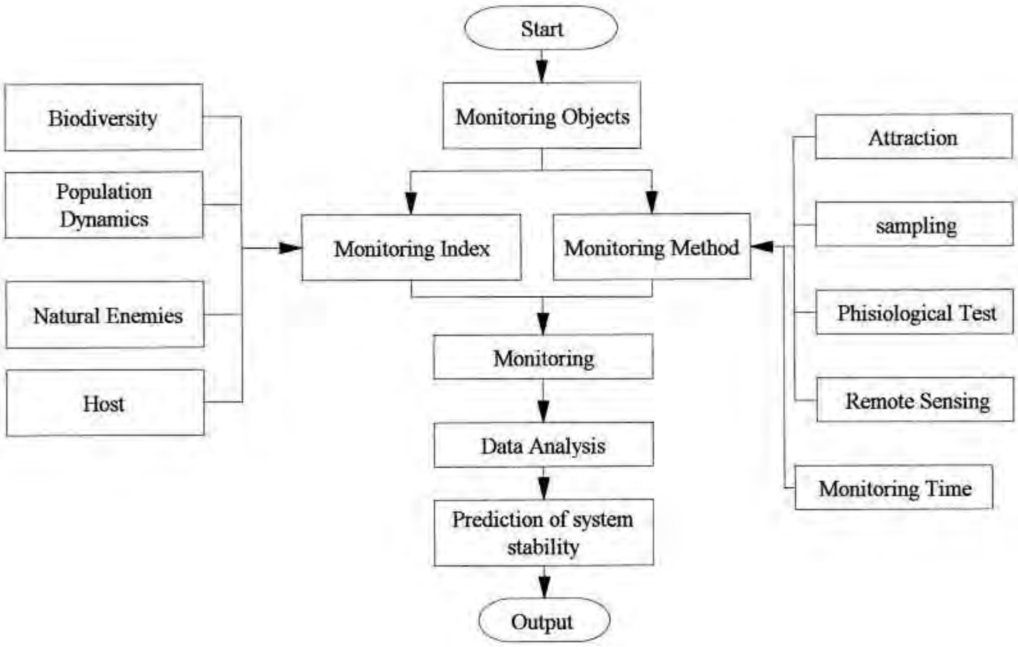

Fig. 2
Monitoring scheme.
Schema di monitoraggio.

Control threshold

Control threshold of EPM is the pest population density level when the pest slips away from the control of the natural enemies. Under the favourite environment condition to the pest, the population density can increase quickly above the threshold. At this circumstance natural enemies can not control the pest immediately so the system loses its balance. Then the pest out break will occur. control should be carried out after the population density reaches the threshold before the out break happens. This threshold is lower than existing economic threshold.

MANAGEMENT TACTICS OF EPM

The key tactic of EPM is to establish a stable system at the beginning. The following factors should be take into consideration: 1) biodiversity at gene, species and system level; 2) resistance of species in the system to main pest in the region; 3) adaptation of the species to the region; 4) system structure which should facilitate the natural enemies.

Maintenance of the system

Based on the continual monitoring and evaluation of the system, regular maintenance of the system is needed to enforce the system. The tactics include: 1) rational management measures, e.g. watering, trimming , thinning; 2) structure regulation, such as vegetation diversification by mountain closure, or planting of shrubs and tree species regulation. There have been some successful examples, e.g. suppression of pine caterpillars (*Dendroctolus* spp.) and control of poplar long horn beetles through diversification of tree species.

Except for above preventive measures, release of natural enemies or other biological control measures can be used when EPM threshold is reached to maintain the system stability by regulation of system element.

Emergence control tactics

By means of the system regulation tactics, the pest outbreak tendency can be reduced to a large extent, but under special weather conditions pest out breaks still can occur. When the pest outbreak has already happened, emergency control tactics have to be used. Biopesticides are the main control agents.

The management goal of EPM is to increase the system stability so as to reduce or avoid the emergency control tactics through the implementation of regular management tactics (DENG, 1998).

RESEARCH APPROCH OF EPM

At the present level of knowledge and technology, EPM cannot be elaborated thoroughly. Efforts should be made in research of the theory and the relevant techniques as regards the following aspects:

1. systematic ecology: self-regulation mechanism of the system, relationship between system biodiversity and stability, structure and stability, system dynamics;
2. relationship between natural enemies and pest from biology, behavior, ecology, chemistry ecology aspects; characteristics of enemies which can work at the beginning of the pest outbreaks; optic release pattern, release quantity and release time of the enemies;
3. determination method of control threshold;

4. establishment of monitoring and prediction system;
5. management technique such as system design, system maintenance tactics, and biological control technology;
6. research on the sociology of EPM, e.g. participation of the public in EPM program and its role in the program, promotion of EPM implementation through the policy, organization, and regulations.

In general, although at the present level of knowledge and technology, EPM cannot be elaborated thoroughly, it is the development approach of pest management in 21st century (XU, ZHANG, 1998). Forest ecological pest management should be included into forest ecosystem management scheme to be implemented and developed. Efforts should be made in research of the ecology of ecosystem and the relevant techniques.

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RIASSUNTO - Lo sviluppo sostenibile delle risorse forestali costituisce la strategia e le linee guida dello sviluppo forestale del 21° secolo. La gestione ecologica dei parassiti forestali (EPM) include la teoria ed i metodi della gestione degli ecosistemi forestali. L'EPM si è sviluppata dalla gestione integrata dei parassiti (IPM) e ne usa molti elementi, ma è basata sul mantenimento e sul sostegno della stabilità naturale degli ecosistemi e sulla soppressione dell'esplosione dei parassiti durante gli stadi iniziali, quando cioè la densità della popolazione è ancora bassa. Attraverso un sistema speciale di raccolta ed elaborazione dei dati (stima della frequenza della comparsa dei parassiti, densità delle popolazioni dei parassiti e dei predatori, ecc.) si può determinare il livello di soglia oltre il quale i parassiti si sottraggono al controllo dei loro nemici naturali e si possono quindi prendere le decisioni sul controllo biologico dei parassiti stessi. L'EPM può risultare più economico dell'IPM, poiché non è basato sull'uso di pratiche costose come l'impiego dei fitofarmaci di sintesi e l'uso massivo dei nemici naturali, sia parassiti che predatori, allevati artificialmente. Il livello attuale delle conoscenze e della tecnologia non permette però un'elaborazione accurata dell'EPM.

AUTHOR

Zhang Zhen, Institute of Forest Environment and Protection, Chinese Academy of Forestry, Beijing, 100091, P. R. China

Comparison of the amenity in three representative forest types of Japan

T. KAGAWA and K. IGAWAHARA

ABSTRACT - It is considered that the amenity of forests differs depending on the forest type. This is because the structures and constituent trees of forests are different. Using questionnaires, we have examined the amenity of three different types of forests, i.e., an evergreen broad-leaved forest, a deciduous broad-leaved forest, and a man-made coniferous forest, in order to get information for future forest improvement. As a result, we found differences in factor weights, which depend on forest type. 1) In the man-made coniferous forest, important factors were: the appearance of forests such as size of trees and shape of stems, and the visibility, which is affected by tree density and height of undergrowth. 2) In the evergreen and deciduous broad-leaved forests, important factors were: the appearance of trees such as their size, the tint in the forests by tint of leaves, and visibility such as tree density.

Key words: analytic hierarchy process, forest, questionnaire, semantic differential technique

INTRODUCTION

With the rising interest in nature and outdoor activities in recent years, recreational activities in forests have revived (OOISHI *et al.*, 1994). One reason is that contact with forests works to refresh the mind and body. Functions of forests are shifting from conventional timber production to amenity-oriented (KAGAWA, 1991). Thus, in order to manage forests to meet the needs of diverse users, it is necessary to evaluate forest amenity and to find characteristics of high-amenity forests.

Gifu Prefecture contains forest types typically found in Japan, such as evergreen broad-leaved forests in warm-temperate zones, deciduous broad-leaved forests in cool-temperate zones, and evergreen coniferous forests in sub-arctic zones. Because forests show diverse structures depending on their environment, we can assume that amenity differs depending on the forest type.

Some of the studies on amenity evaluation of forests published so far include a study which analyzed forest impressions using the SD (Semantic Differential) Technique, one which figured a structure of forest amenity factors and its factor weights by applying AHP (Analytic Hierarchy Process), and one which figured evaluation standards for the landscape in the forest.

Most analyses of forest impressions have used visual aids like photographs, but only a few have used in situ studies. Moreover, most in situ studies were undertaken in forests of the same type. Amenity structures of man-made *Cryptomeria japonica* forests and rural secondary forests and standards for evaluations of the landscape in *Chamaecyparis obtusa* forests were figured using AHP; however, because the amenity structure is unique in each case, it is difficult to evaluate the amenity of different types of forests using the same standard (KAGAWA, 1991).

Therefore, this study has aimed to evaluate amenity using questionnaires given to the same subject group for three different forest types, to compare the results, and to get information for forest management in the future.

METHOD OF THE STUDY

Evaluation of mental impression

The forests in question were three types that people are considered to come in closest contact with in Gifu Prefecture; an evergreen broad-leaved forest in a warm-temperate zone (evergreen broad-leaved forest), a deciduous broad-leaved forest in a cool-temperate zone (deciduous broad-leaved forest), and a man-made coniferous forest. Then, we evaluated the amenity of these forest types. The evaluation was undertaken by filling out questionnaires which were distributed after subjects had strolled through these forests. Questionnaires were based on assumed analyses using the SD technique and AHP.

Forest impression by SD technique

In order to determine factors which create a forest impression, we used the SD technique after strolling through the forests. From the results, we examined the relation between the difference of forest types and factors which decide forest impression. We used an evaluation method of 7 levels (+3, +2, +1, 0, -1, -2, and -3) of 15 adjectives (evaluation standards) which are regarded as important to describe forests. Based on the results, we established a correlation coefficient between evaluation standards, and using the SVC technique and varimax rotation, we analyzed factors for each forest type (SUZUKI, HORI, 1989).

WEIGHTS OF AMENITY FACTORS BY AHP

We examined amenity structures, referring to existing literature (KAGAWA, 1991). Essentially, deeper levels for evaluation are assumed for nature and environment in the forests. However, in this study we used deeper levels for the evaluation of the landscape in the forest on which immediate effects by forest management are expected (SUZUKI, HORI, 1989). Then, based on these results, we examined high-amenity direction for forest management. In addition, we used three or less factors in the same level in order not to complicate pair comparison as AHP was undertaken using questionnaires.

Amenity structure was shown in the questionnaires for evaluation, and an explanation about amenity factors was given before evaluation. After that, we made subjects evaluate the relative importance of the factors in the forest. Then, based on valid answers, we figured the geometric mean and weights of each factor.

Description of subjects

Subjects were 22 1st-year-students (20 male, 2 female) attending Gifu Prefecture College of Forestry. Tab. 1 shows their attributes. In the subject group, 14 people (64% of the subjects) answered "often" or "sometimes" to the question "Do you stroll through forests" and 55% answered "yes" to the question "Do you like strolling through forests?". In addition, 18% had taken courses on forests before entering the school.

STUDIED FORESTS

Evergreen broad-leaved forest

In regard to evergreen broad-leaved forests in warm-temperate zone, we evaluated mental impressions on 20th May 1999, in a *Castanopsis cuspidata* and *Quercus glauca* forest on Mt. Kongou in Gifu City. Mt. Kongou, a crown forest where cutting has been prohibited for many years, is a natural evergreen broad-leaved forest containing mainly *Castanopsis cuspidata*, a typical species of Gifu Prefecture. Tab. 2 shows data of the objective forest. The weather at the time of examination was fair; the air temperature outside the forest was 32.0, but only 21.5 inside the forest, making a large temperature differential of 10.5. The environment inside the forest was comfortable. This forest has developed a layer structure. In the tree and sub-tree layers, *Captanopsis cuspidata* and *Quercus glauca* about 20-35 cm in DBH (diameter at breast height), were dominant. Undergrowth consisted of a shrub layer which was about 2.0 m in height, containing *Cleyara japonica*, *Eurya japonica*, *Pieris japonica*, and *Sagina japonica*, and a herb layer

TABLE 1
Attributes of subjects.
Classe d'età dei soggetti intervistati.

Age		Do you stroll through forests?		Do you like strolling through forests?		Circumstance before entering the school	
In teens	17	Often	3	Yes	12	Courses on forests	4
In twenties	4	Sometimes	11	Not sure	10	High school of forestry	5
In sixties	1	Never	8	No	0	Others	13

TABLE 2
Date of objective forests.
Caratteristiche delle foreste analizzate.

	Dominant species	DBH of dominant species (cm)	Tree height of dominant species (m)	Tree density (trees/ha)	Total basal area of DBH (m^2/ha)
Evergreen broad-leaved forest	*Castanopsis cuspidata* *Quercus glauca*	20-35	13	——	——
Deciduous broad-leaved forest	*Fagus crenata*	31.6-55.2 45	20	1,320	34.7
Man-made coniferous forest	*Cryptomeria japonica*	9.7-53.8 30.9	21	660	55.7

comprising *Vaccinium hirtum*, *Mitchella undulata*, etc. The width of the walking path was 3-4 m.

Deciduous broad-leaved forests

We evaluated mental impression of a deciduous broad-leaved forest in a cool-temperate zone, on 2nd June 1999, in a *Fagus crenata* forest near the west Ure pass, Kiyomi Village. The weather of the day was partly sunny. The air temperature differential between outside the forest (31.6°C) and inside (20.3°C) was 11.3°C, and the environment inside the forest was comfortable. In the tree layer, *Fagus crenata* was dominant, average diameter of which was 45.0 cm. *Betula grossa*, *Ilex macropoda*, *Acer rufinerve* and other grasses covered the sub-tree layer. Undergrowth consisted of a shrub layer containing *Acanthopanax sciadophylloides*, *Magnolia salicifolia*, *Stewartia pseudocamellia*, *Hydrangea paniculata*, and so forth, which were 1.5-3.5 m in height, and a herb layer consisting entirely of *Sasa senanensis* which averaged 1.0 m in height. The tree density up to shrub layer was 1,320 trees, and the total basal area at DBH was 34.7. This is a secondary forest of *Fagus crenata* which is often seen in cool-temperate zones, whose subsoil is covered with Sasa. The walking path was about 1.2 m in width, paved with stone.

Man-made coniferous forest

We evaluated mental impression on 14th July 1999, in a man-made *Cryptomeria japonica* forest in Kamagaya, Ijira Village. The weather was cloudy, with scattered rain. The air temperature and the humidity inside the forest were 27.0°C and 98%, respectively, and the environment was soggy and uncomfortable. Trees averaged 30.9 cm in diameter, density of 660 trees ha^{-1}, and the basal area at DBH was 55.7. The average bole height was high, 10.0 m, and dead branches were pruned. The forest floor was light, and 100% of undergrowth was covered. A herb layer, consisting of *Rubus buergeri*, *Achyranthes japonica*, *Boehmeria spicata*, *Polygonum Blumei*, and *Boehmeria nivea*, mainly dominated undergrowth and no shrub layer was seen. The herb layer was cut into about 2.0 m in height, in order to grow *Lilium auratum*. This forest represents a middle-aged man-made *Cryptomeria japonica* forest which is well-managed.

RESULTS OF AMENITY EVALUATION

We analyzed valid answers, which excluded answers without full-entry. The number of valid answers for both the SD technique and AHP were: 17 for the evergreen broad-leaved forest, 21 for the deciduous broad-leaved forest, and 22 for the man-made coniferous forest.

Analysis of impression in the forests using the SD Technique - Evergreen broad-leaved forest

Four factors were identified whose endemic values were 1.0 or above before rotation of factor axis, and as cumulative contributing ratio was 73.7%, the main factors were set at 4 (Tab. 3). We named the first factor (rate of cumulative contribution; 26.7%) "comfort", which was represented by evaluation standards such as 'comfortable-uncomfortable', or 'fresh-dull'. The second one (21.9%) was called as "vigor", which was represented by standards such as 'dignified-undignified', 'noble-poor', or 'vigorous-feeble'. The third one (14.9%) was called as "friendliness" which was represented by 'friendly-unfriendly', and the fourth one (10.2%) was called as "light".

Deciduous broad-leaved forest

In the deciduous broad-leaved forest, five factors

TABLE 3
Results of factor analysis.
Risultati dell'analisi dei fattori.

Evaluation standards	Loading dose of factors 1st factor Comfort	 2nd factor Vigor	 3rd factor Friendliness	 4th factor Lightness
Beautiful-Ugly	0.922	0.189	0.140	0.057
Comfortable-Uncomfortable	0.910	0.029	0.037	0.035
Diverse-Monotonous	0.860	0.172	0.297	-0.174
Like-Dislike	0.757	0.566	0.118	0.048
Fresh-Dull	0.673	0.272	0.268	0.035
Dignified-Undignified	0.151	0.918	-0.099	-0.106
Holy-Common	0.260	0.768	0.061	0.222
Noble-Poor	0.311	0.766	0.178	0.078
Vigorous-Feeble	-0.001	0.691	0.302	-0.307
Friendly-Unfriendly	0.264	-0.212	0.747	-0.007
Lively-Unlively	-0.022	0.377	0.740	-0.195
Open-Close	0.191	0.208	0.608	0.061
Natural-Artificial	0.483	0.037	0.566	0.018
Light-Dark	0.115	0.225	-0.199	-0.860
Cool-Warm	-0.112	-0.215	0.272	-0.796
Contributing ratio	26.700	21.900	14.900	10.200

were identified and the rate of cumulative contribution was 80.9%. The first factor (22.2%) was identified as "naturalness" which was represented by 'natural', or 'lively'. The second one (18.6%) was called "comfort" and characterized by 'fresh', 'comfortable', the third one (16,1%) was "friendliness" by 'friendly', the fourth one (14.7%) was "openness" by 'light' or 'open', and the fifth one (9.3%) was "coolness".

Man-made coniferous forest

In the man-made coniferous forest, four factors were identified and the rate of cumulative contribution was 76.9%. The first factor was "openness-comfort" which was represented by 'open', 'light', 'comfortable', or 'fresh'. The second one (20.9%) was "vigor" by 'vigorous', 'noble', or 'dignified'. The third one (19.1%) was "naturalness" by 'diverse' or 'natural', and the fourth one (11.2%) was "holiness" (HORI, 1988).

Among these main factors, we observed that each common factor has a common evaluation standard (SUZUKI, HORI, 1989). We realize that the common factor among all forest types is "comfort". Moreover, we observed, as a common factor, "friendliness" between the evergreen and deciduous broad-leaved forests, "vigor" between the evergreen broad-leaved forest and the man-made coniferous forest, and "naturalness" and "openness" between the deciduous broad-leaved forest and the man-made coniferous forest (SUZUKI, HORI, 1989). On the other hand, some factors were observed for only one forest type, i.e., "light" in the evergreen broad-leaved forest, "coolness" in the deciduous broad-leaved forest, and "holiness" in the man-made coniferous forest. In other words, it was regarded that the impression of the inside of the forest was decided by a common factor and a factor which depended on the forest type, and that the common factor was "comfort".

Factor evaluation for amenities inside forests

For all forest types, the factor which had the most weight was naturalness (Tab. 4). In regard to the evergreen broad-leaved forest (w: 0.46) and the deciduous broad-leaved forest (w: 0.58), that was understandable because both forests had a high degree of biological naturalness. However, the man-made coniferous forest (w: 0.41) was maintained very well.

Each person has a different concept of naturalness; some people regard green forests as natural, and some regard virgin forests as natural. In regard to the man-made coniferous forest, rich undergrowth by proper management apparently made subjects evaluate it as highly natural, so that "naturalness" in this context expresses not only biological naturalness (SUZUKI, HORI, 1989).

The order of factor weights in the evergreen and deciduous broad-leaved forests was the same; 1) naturalness, 2) environment inside forest, and 3) landscape in the forest. On the other hand, in the man-made coniferous forest, the order was 1) naturalness, 2) landscape in the forest, and 3) environment in the forest.

It is regarded that decisive factors for forest impression such as comfort and naturalness affect amenity factors at this level. In other words, beauty, liveliness, and vigor, which some factors include, relate to landscape in the forest, comfort and freshness to environment inside forest, and naturalness and diversity to naturalness of forests.

Factor evaluation for landscape in the forest

For all forest types, the appearance of trees was the biggest in factor weight (Tab. 5). The order of factor

TABLE 4
Factor weights for amenities inside forests.
Incidenza dei fattori di amenità all'interno delle foreste.

	Evergreen broad-leaved forest	Deciduous broad-leaved forest	Man-made coniferous forest
Landscape inside forest	0.22	0.19	0.30
Environment inside forest	0.32	0.23	0.29
Naturalness	0.46	0.58	0.41
C.I. (Consistency Index)	0.003	0.008	0.036
C.R. (Consistency Ratio)	0.004	0.014	0.062

TABLE 5
Factor weights for landscape inside forests.
Incidenza dei fattori paesaggistici all'interno delle foreste.

	Evergreen broad-leaved forest	Deciduous broad-leaved forest	Man-made coniferous forest
Appearance of trees	0.46	0.39	0.40
Tint in the forest	0.31	0.32	0.28
Visibility	0.22	0.29	0.32
C.I.	0.008	0.000	0.009
C.R.	0.014	0.000	0.015

weights in the evergreen and deciduous broad-leaved forests was the same; 1) the appearance of trees, 2) the tint in the forest, and 3) the visibility. On the other hand, in the man-made coniferous forest, the order was 1) the appearance of trees, 2) the visibility, and 3) the tint in the forest. These assessments characterize the landscape in the forests in this study. Vigor, which determines impressions in the evergreen broad-leaved forest and the man-made coniferous forest, seems to affect the landscape in the forest, and openness, which is common in both the deciduous broad-leaved forest and the man-made coniferous forest, seems to affect visibility.

Factor evaluation for the appearance of trees

For all forest types, the size of trees was the biggest in factor weight which made up the appearance of trees (Tab. 6). In regard to the man-made coniferous forest, there was little difference between the size of the tree and the shape of the stem. Both factors are important because *Cryptomeria japonica* trees in the man-made coniferous forest were thick enough (averaging 30.9 cm in diameter), and because the stems were straight. Moreover, it is considered that this thick, straight shape of stems affects "holiness", the factor which decides the impression of the man-made coniferous forest (HORI, 1988).

Factor evaluation for the tint in the forest

In regard to factor weight which made up the tint in the forest, the evergreen broad-leaved forest and the deciduous broad-leaved forest showed the same tendency (Tab. 7). The order of factor weights was 1) the tint of leaves, and 2) the tint of stems. On the other hand, for the man-made coniferous forest, the order was the opposite. Thus it seems that this difference depends on forest structure. In other words, in the evergreen or deciduous broad-leaved forests, which had wide layer structures from tree layer down to shrub layer, the tint of leaves was evaluated, and in the man-made coniferous forest, whose clear length in the tree layer was high enough, the tint of stems was evaluated. From this, it seems that "friendliness", which makes up an impression for the evergreen or deciduous broad-leaved forests, affects the tint in the forest.

Factor evaluation for the visibility

Among the visibility factors, tree density was the biggest weight for all forest types (Tab. 8), particularly, for the evergreen broad-leaved forest (w: 0.50) and the deciduous broad-leaved forest (w: 0.46). After that, factor order was as follows: 1) the height of branches, and 2) the height of undergrowth. This

TABLE 6
Factor weights for appearance of trees.
Incidenza dei fattori di apparenza degli alberi.

	Evergreen broad-leaved forest	Deciduous broad-leaved forest	Man-made coniferous forest
Shape of leaves	0.29	0.24	0.27
Size of trees	0.42	0.47	0.37
Shape of stems	0.29	0.30	0.35
C.I.	0.006	0.001	0.006
C.R.	0.010	0.001	0.001

TABLE 7
Factor weights for tint in the forest.
Incidenza dei fattori cromatici all'interno delle foreste.

	Evergreen broad-leaved forest	Deciduous broad-leaved forest	Man-made coniferous forest
Tint of stems	0.42	0.39	0.51
Tint of leaves	0.58	0.61	0.49
C.I.	0.000	0.000	0.000
C.R.	0.000	0.000	0.000

TABLE 8
Factor weights for visibility.
Incidenza dei fattori visivi.

	Evergreen broad-leaved forest	Deciduous broad-leaved forest	Man-made coniferous forest
Tree density	0.50	0.46	0.36
Height of branches	0.26	0.29	0.30
Height of undergrowth	0.24	0.25	0.34
C.I.	0.000	0.005	0.012
C.R.	0.000	0.009	0.020

indicates that the tree density was important for the visibility in the evergreen and deciduous broad-leaved forests. On the other hand, in regard to the man-made coniferous forest, little difference in weight was observed among the tree density, the height of undergrowth, and the height of branches. This shows that 660 trees/ha in tree density, 0.2 m in height of undergrowth, and 11.0 m in height of branches were evaluated as equal.

Direction for high amenity forest management

In this study, we undertook two kinds of amenity evaluation in the field to forests of three different types of forests, taking 1st-year students in Gifu Prefectural College of Forestry as subjects.

As a result of impression analysis inside forests using SD Technique, we concluded that factors which determined forest impression consisted of both factors which were common without regard to forest types, and ones which were unique to a certain forest type. This indicates that "comfort" should be a keyword for forest improvement.

As a result of application of AHP which had the same amenity structure, and of comparison among weights of amenity factors, especially the landscape in the forest, which were observed in the different types of forests, these following points were considered important for improving the amenity of forests (Kagawa, 1991).

In natural forests such as evergreen or deciduous broad-leaved forests, which have diverse shapes of stems, and consist of diverse species of trees, the appearance of trees which depends on their size, the tint in the forest which depends on the tint of leaves, and the visibility which depends on tree density, are important (Suzuki, Hori, 1989).

In a forest such as a man-made coniferous forest, which consists of a sole tree species that has straight stems, the important factors are the appearance of trees which depends on their size and the shape of their stems, and the visibility which depends on tree density and height of undergrowth.

Conclusion

In this study the common factor affecting subjects' impression of the forest was "comfort", but each type of forests also has unique points to pay attention to in order to improve their amenity.

However, we have not yet established a numeral barometer for improvement. For instance, what is the best tree density for a deciduous broad-leaved forest, or what number of trees par ha could be a barometer for this case? In future we need to examine such potential barometers. Also, as the *Castanopsis cuspidate* and *Quercus glauca* forest, the *Fagus forest*, and the *Cryptomeria japonica* forest which we studied here are typical forests of Gifu, we need to evaluate the amenity of a more diverse group.

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RIASSUNTO - Si ritiene che il diverso grado di amenità delle foreste dipenda dal tipo stesso di foresta, poiché queste differiscono sia nella struttura che nella composizione. Attraverso l'uso di un questionario è stato esaminato il grado di amenità di tre diversi tipi di foreste (una foresta di latifoglie sempreverdi, una foresta di latifoglie decidue ed una foresta artificiale di conifere) per ottenere informazioni da utilizzare nel miglioramento delle foreste. I risultati mostrano che la diversa incidenza dei fattori di valutazione sono funzione del tipo di foresta. 1) Nella foresta artificiale di conifere i fattori importanti sono: l'aspetto della foresta, come ad esempio la grandezza degli alberi e la forma delle branche, e la visibilità, che è dipendente dalla densità degli alberi e dall'altezza del sottobosco. 2) Nelle foreste di latifoglie, sia sempreverdi che decidue, i fattori importanti sono: l'aspetto degli alberi, come ad esempio la loro grandezza ed il colore delle foglie, ed i fattori di visibilità, come ad esempio la densità degli alberi.

AUTHORS

Takahide Kagawa, K. Igawahara, Forestry and Forest Products Research Institute, Japan

The role of interpretation of cultural and natural resources in ecotourism development

T.T. CABLE

ABSTRACT - Individuals, society, the organizations that protect cultural and natural resources, and ecotourism firms all benefit from interpretation in ecotourism developments. Interpretation can enhance the development and sustainability of society, so we can live together more peaceably and more productively. Interpretation can play an important role as a management tool by changing visitor behavior. Interpreters spread the message of cultural or natural resource values, and conveys the organizations's role in protecting them. Interpreters are image-makers of agencies and organizations. Good information and a positive image builds public support for the management organization. By assisting the resource managers upon which ecotourism firms depend, and by enhancing the tourism experience, interpretation benefits ecotourism companies.

Key words: cultural resources, ecotourism, natural resource management

INTRODUCTION

"*Interpretation is good for tourism and tourism is good for interpretation.*"

What is interpretation?

A classic definition of interpretation is Freeman Tilden's half century old statement that interpretation is, "*an educational activity which aims to reveal meanings and relationships through the use of original objects, by first-hand experiences, and by illustrative media, rather than simply to communicate factual information*" (TILDEN, 1977). This definition focuses on *how* to interpret and on the educational function of interpretation. But interpretation is more than just educational - it must be a recreational activity to attract and hold audiences and it should be an inspirational activity if done well. So an expanded definition might be that "interpretation is an educational and recreational activity conducted in informal settings such as national parks, historic sites, museums, zoos, and nature preserves, whereby personal meaning is assigned to natural or cultural resources in an inspiring and entertaining manner."

People often find the term "interpretation" confusing when applied to tour leaders, park rangers, museum guides or zoo docents. Yet, it has meaning in that these interpreters take objects, organisms, ecological process, and historical events which are "foreign" to the general public and they "interpret" them, i.e., make them understandable and meaningful. Interpreters are meaning-makers. It has been said that, "One of the things about being human is learning to see beyond the ordinary." Interpretation helps people see beyond the ordinary.

Why interpretation?

The benefits from interpretation to the development of ecotourism fall into the following categories: benefits to agencies managing natural or cultural resources being visited, benefits to the individuals who participate in the ecotourism experience, and benefits to firms providing the ecotourism opportunities. Moreover, in the case of domestic ecotourism, interpretation can benefit society in that country. This paper presents the role of interpretation in ecotourism development in terms of the benefits provided by interpretation.

VALUES FOR CULTURAL AND NATURAL RESOURCE MANAGERS

"In the final analysis, people protect only what they love." - Jacques Cousteau

One concern associated with the development of ecotourism is the effect of tourism visitation and infrastructure on the natural or cultural resources that provide the tourism attraction. Interpretation can cause people to love or at least appreciate a cultural or natural resource, thereby providing a motivation to protect and care for it.

Since the early days of interpretation it has been recognized that interpretation could potentially have positive management ramifications. In fact, on July 20, 1919, Stephen Mather, the first Director of the U.S. National Park Service after hearing an exceptional interpretive talk, decided that this was precisely what he needed to have in the National Parks to "counteract those persons who would selfishly destroy park values." For many years the motto "*Through interpretation education; through education appreciation; through appreciation protection*" was used to articulate the idea of interpretation as a management tool. Today, the park management literature contains many specific references to interpretation being effectively used as a management tool to provide the following benefits: 1) decreased vandalism; 2) decreased poaching of park fish and wildlife; 3) decreased depreciative behaviors such as souvenir collecting and unauthorized motor bike use; 4) increased compliance with park regulations, 5) increased safety, and 6) increased public support for park policies and management practices (e.g., prescribed burning). These benefits collectively raise the visitation carrying capacity of a cultural or natural resource site. Interpretation *can* solve specific management problems related to both resource protection and providing visitors with an enjoyable and safe ecotourism experience. In fact, interpretation programs have been shown to save lives, particularly by preventing drowning or dangerous wildlife encounters in tourism areas.

Whenever we speak of using interpretation as a management tool we are really referring to modifying people's behavior, whether it be discouraging littering or encouraging donations to help preserve a site. The literature abounds with persuasion theories and theories explaining behavior modification. One such theory applied to interpretation is Fishbein's Theory of Reason Action (FISHBEIN, 1975). It identifies beliefs and evaluations as determinants of attitudes, and attitudes as precursors of intentions. Intentions then are linked to actual behaviors. Although there is a strong correlation between intentions and behavior, it is not a perfect correlation. Some people do not have the ability to, or are prevented from, carrying out their intentions. For example, a tourist may intend on donating to a museum, but then finds that she has no money with her at the time. However, changes in intentions imply changes in behaviors, assuming that intentions are realistically defined.

The determinants of attitudes (beliefs and evaluations) are based upon information which may be correct or incorrect. Interpretation can facilitate integration of new or better information into changes of beliefs which affect changes in attitudes. Therefore, interpretation can affect people's attitudes, which in turn can affect intentions and behavior.

However, not all attitude changes will be reflected in behavior changes. Fishbein's model includes the influence of subjective norms on behavioral intentions. Norms may be so strong that they do not allow attitude changes to alter intentions. Interpreters, whether tour guides or park rangers or museum volunteers, can powerfully affect the norms of a group. Therefore, interpreters can change behavior by changing attitudes, norms, or both.

In summary, as Cousteau said, "people protect only what they love." Interpretation can cause people to love significant resources. Changes in attitudes regarding the resources or the managing organization may predict behavioral changes, with the caveat that attitudes combine with social norms to produce intentions. Interpreters can affect both norms and attitudes, thereby promoting favorable behaviors. In cases where the appropriate norms and attitudes already exist (i.e., when you are "preaching to the choir") interpretation reinforces these attitudes and norms, and may reinforce existing appropriate behaviors. When positively affecting visitor behavior, interpreters in ecotourism settings work with the resource managers in a mutually beneficial way by helping them protect the resources upon which the tourism is based.

BENEFITS TO THE ECOTOURIST

The benefits of interpretation received by ecotourists can be classified as recreational, educational, or inspirational. Of course, these categories overlap. People attend interpretive programs or facilities because they find that acquiring knowledge is an enjoyable and enriching experience in itself, and that by having more knowledge about the resources of an area their visits are more meaningful and enjoyable. For example, knowing the best places to see rare birds in a park would facilitate a more enjoyable experience for a visiting birdwatcher. Likewise, having an understanding of a unique geologic feature could result in a family stopping to look closely at it thereby enhancing their trip, whereas otherwise they would have driven past it without even noticing it. Without interpretation they may have been severely disappointed later upon learning that they had missed something special.

Although people find learning to be a positive experience, most people would not spend their leisure time attending dry, technical lectures. All interpretation must be recreational. Providing a recreational experience should not be taken lightly. Twenty-three hundred years ago, in his book *Politics*, Aristotle linked the existence of the "state" with the purpose of securing happiness for its citizens. Likewise, in the Declaration of Independence, Thomas Jefferson included the "pursuit of happiness" as one of three unalienable rights (along with life and liberty). In a very real sense interpreters who provide recreational experiences are manufacturing happiness, i.e. providing the opportunity for pleasurable experiences. The Disney Corporation (masters of the art of interpretation and the provision of recreation), institutionalized this focus by literally including in every job description the primary task of "providing a happy experience for the guests". Such "happy experiences" are necessary to maintain a high quality of life for individuals. They have been shown to decrease stress, increase self-reliance and self esteem, and improve mental and physical health.

In this light, it is clear that providing recreational experiences is a noble undertaking. Although currently it is not valued as such by society, it ranks in importance with health care providers, social workers, educators and other professions that contribute directly to human welfare.

Good interpretation is fun; but the best interpretation is more than recreational - it is *inspirational*. Discovering the beauty in the workmanship of a piece of antique furniture, a special adaptation of an insect, or a majestic panoramic view, is not strictly educational nor merely "fun." It is something more. The feelings generated by such interpretive experiences are profound, almost indescribable. Balancing the recreational, educational, and inspirational facets of interpretation in every interpretive task is one of the most difficult challenges facing interpreters. Interpreters particularly have difficulty in incorporating a "happy medium" of both information and entertainment in their interpretive efforts. A common example of this lack of balance is the interpretive talk which takes the form of a speech or lecture, lacking a recreational or entertainment component. At the other extreme are presentations which may be humorous or may involve games and other fun activities but which may not have enough information to have any educational value. Freeman Tilden, a founding father of interpretation in the U.S., noted that, "information, as such, is not interpretation. Interpretation is revelation based upon information. They are entirely different things. However, all interpretation includes information" and "information is the raw material of interpretation." Naturalist John Burroughs' succinct goal was to "enjoy understandingly." This balanced approach to education and recreation could serve as both a personal goal for interpreters, and as a goal for the audiences they serve.

INTERPRETING FOR INDIVIDUAL GROWTH

Many theories attempt to explain people's motivation to participate in interpretive programs or visit interpretive facilities. Abraham Maslow developed one such theory that offers insights into these motivations (MASLOW, 1987). His theory suggested a hierarchy of needs (or drives) beginning with basic needs of survival and security and going up to more sophisticated and socially oriented needs such as the need to belong to a group or be loved.

The basic physiological needs associated with survival are the strongest. Most people can appreciate how difficult it would be to pursue higher pursuits such as learning if you are starving.

Maslow characterized "Basic Needs" as physiological (e.g., air, food, water, sleep, and sex), safety, and security needs. He categorized higher needs as "Growth Needs." Growth Needs include love and belonging, esteem and self actualization. The pinnacle of growth is self-actualization. Maslow identified humanly important self-actualization motives and referred to them as "meta-needs". According to Maslow a person whose security needs are met but whose meta-needs are not met, falls into a "syndrome of decay" and experiences despair, apathy, and alienation. Although Maslow thought the desire for self-actualization is universal, he recognized that it was very difficult to attain because it was dependent on the lower needs being met. Most are lower on the hierarchy, being concerned with self-esteem, love, or security.

A strong interpretive program as part of an ecotourism experience can, and will, meet personal growth needs of the clients and propel the participants along to richer living with more sensitivity toward their environment, their cultural heritage, and increased self-fulfillment. Over time, the interpretive faculty is developed in the individual tourist so they can interpret to others and in a sense to themselves.

Tab. 1 illustrates this "Hierarchy of Needs" and explains how interpreters can meet the needs of visitors regardless of their place in Maslow's theoretical framework.

BENEFITS TO SOCIETY

In aggregate, the aforementioned personal growth benefits to individuals also benefit society at large. Moreover, because interpretation is a *recreational* activity, societal benefits attributed to all recreation in general may be produced from interpretation. Benefits associated with recreation include: improved public health, decreased crime rates, family stability, and community unity. Interpretation also can contribute to society in the following three ways in the context of education and ecotourism.

Identity with the land and culture

Interpretation as part of domestic ecotourism encourages the citizens of a nation to identify with the landscape and the natural and cultural resources of their nation. This identification allows each individual to feel a part of the nation, and thereby promotes unity and "belonging". National identity and pride grow from a sense of where one is, of the special qualities of the immediate surroundings. This healthy pride may prevent foolish actions that could destroy the character of the place by helping us understand the consequences of individual acts or community proposals. Likewise, if citizens enjoy the diversity of their societies customs, styles, and attitudes, they may be more tolerant of those who are "different" and therefore "dangerous".

A remarkable example is Indonesia's interpretation of its own cultural identity as being a unique blending of many traditions. In the beautiful "Mini-Indonesia" park near Jakarta, customs, clothing, environment and architecture of the different cultural components of the nation are featured in a beautiful setting. This elegant folk museum somehow unites the diversity in a most impressive, positive learning experience for

TABLE 1
Expanded levels of personal needs and how interpreters can meet them.
Categorie di bisogni personali e come gli interpreti possono soddisfarli.

Levels of need	How interpreters can meet personal needs
Self-actualization	Provide resources for independent exploration. Help visitors to develop interpretive materials from their own perspectives. Assist visitors to develop their own campfire programs.
Aesthetic	Offer seminars for reading and discussion with experts in diverse fields related to visitor interests. Lead guided walks to places of special or unusual interest. Bring in outside specialists for talks and visits (e.g., artists, scientists, top managers).
Understanding	Provide access to reports, plans, budgets, etc. Provide means for visitors to ask questions about policy, regulations, science, etc. Post questions and responses in convenient locations for all to see. Provide interpretive "exercises" Experiments, and other environmental education activities and tasks to allow visitors to perform specified tasks on their own time.
Knowledge	Provide access to data and diverse library resources. Provide times so interpreters can talk with visitors in an unstructured way. Arrange for visitors to see practical applications of principles, concepts, and ideas.
Esteem	Publicize a visitor's performance on bulletin boards, park newsletters, and campfire programs. Give visitors significant responsibilities on walks, at campfires, and slide shows.
Love and belonging	Call the visitor by name-ask for it and use it. Visit the campground and other park areas where people gather. Express your pleasure in working with visitors and with the individual.
Safety and security	Encourage and permit continued study in areas of visitor interest and ability. Publish park policies and follow them consistently. Consistently avoid punishment and sarcasm.
Physiological needs	Provide strong, consistent safety measures, making visitors aware of them. Have trained first-aid personnel and equipment in the area. Provide for health and sanitation.

Indonesians and visitors from abroad.

Interpretation of the natural landscape played a role in developing nationalism in the United States. In the 1800's, artists and writers expressed the national identity in the land's natural beauty. The American landscape became a "wellspring of nationalism." Wild nature provided the character of American philosophy and culture. Interpretation to tourists at U.S. National Parks still plays a role in how Americans view themselves and their country.

A nation whose citizens understand their historic and natural resources is a nation that may survive longer than one where citizens have little sense of the aesthetic and cultural value of their land. One of Abraham Lincoln's sentiments was that a nation with little regard for its past has little hope for its future. The heritage of any nation's past lies in its natural resources and its special historic sites. The professional interpreter's task and privilege is to bring people into an understanding and appreciation of that heritage.

Increased Awareness of Global Environment

As we approach and surpass the earth's capacity to sustain human population levels, we face many perplexing questions and must place high priority on the protection of ecological systems globally. Debate over these issues is rampant. For the people to get the facts and better understand these complex puzzles, interpretation offers experience in the natural world to give them the practical framework to better perceive the problems and alternative solutions. Travel and tourism causes people to broaden their perspectives to think globally, rather than provincially, and specifically, rather than abstractly.

Help us develop an ethical sense of our place and role in the world.

To get people to care enough to change their lives, their values must be shaped by an understanding and appreciation of their own place and role in the world. We need stories of where we are, of what happened once upon a time and the meanings of these events for the present and future. We need to know the natural history of the many species that cohabit the planet with us, the rocks that support and shelter us, and the natural processes that control our destiny as a species. We need to recognize the intrinsic worth of fossils, artifacts, living plants and animals, and other peoples, how they bring us value and how we, as the "wise overseers" of the planet, relate to them.

BENEFITS OF INTERPRETATION TO ECOTOURISM FIRMS

Ecotourism firms benefit from offering strong interpretation efforts in two significant ways. First, studies show that people benefit from and enjoy interpretation. Just as with any other commodity or product, as clients' experiences are enhanced they will be more likely to purchase more such experiences from that supplier. Interpretation that is fun, educational, and inspirational is good business.

A second benefit of interpretation to ecotourism firms is that it can improve relationships with resource managers and their agencies. By using interpretation as a tool to help managers meet their goals of resource protection and increasing public support and cooperation, the ecotourism firm becomes part of the management team. Interpretation can soften the impacts of tourists and lessen the demands made on the management agency. Rather than causing problems by increasing visitation and the associated impacts, the firm is now part of the solution in dealing with such problems. Working toward good relations with the resource managers who provide the site and foundation for ecotourism is also good business.

CONCLUSION

Why include interpretation in ecotourism developments? Because individuals, society, the organizations that protect cultural and natural resources, and ecotourism firms all benefit from it. Interpretation can help people enjoy their travels more and can lift them beyond the basic levels existence to heightened awareness and understanding of their environment and themselves. It can enhance the development and sustainability of society, so we can live together more peaceably and more productively. Interpretation can play an important role as a management tool by changing visitor behavior. Interpreters spread the message of cultural or natural resource values, and conveys the organizations's role in protecting them. Interpreters are image-makers of agencies and organizations. Good information and a positive image builds public support for the management organization. By assisting the resource managers upon which ecotourism firms depend, and by enhancing the tourism experience, interpretation benefits ecotourism companies. Former U.S. President Theodore Roosevelt said, "There is nothing more practical in the end that the preservation of anything that appeals to the higher emotions." Interpretation in ecotourism settings appeals to the higher emotions. Therefore, if Roosevelt was correct, including interpretation as part of ecotourism development is eminently practical.

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RIASSUNTO - Gli individui, la società, le organizzazioni che proteggono le risorse culturali e naturali e le imprese di ecoturismo beneficiano tutti dell'interpretazione[1] nello sviluppo dell'ecoturismo. L'interpretazione può contribuire ad aumentare lo sviluppo e la sostenibilità della società, in modo che si possa vivere in modo più pacifico e produttivo. L'interpretazione, cambiando il comportamento del visitatore, può avere un ruolo importante come strumento di gestione. Gli interpreti diffondono il messaggio dei valori delle risorse culturali e naturali e trasmettono l'idea del ruolo degli organizzatori nella loro protezione. Gli interpreti sono dei creatori d'immagine delle agenzie e delle organizzazioni. Una buona informazione ed un'immagine positiva contribuiscono a determinare un sostegno pubblico per le organizzazioni di gestione. L'interpretazione, aiutando i manager delle risorse, da cui dipendono le aziende ecoturistiche, ed aumentando l'esperienza del turismo, costituisce un beneficio per le imprese di ecoturismo.

[1]Il concetto di *interpretation* è stato introdotto da Tilden (TILDEN, 1977) con lo scopo di modificare l'atteggiamento dei visitatori di luoghi di interesse culturale e naturale, tramite un programma di esperienze stimolanti ed educative condotto da persone esperte nel campo.

AUTHOR

Ted T. Cable, Dept. of Horticulture, Forestry, and Recreation Resources, 2021 Throckmorton Hall, Kansas State University, Manhattan, KS 66506, USA

Streambank stability of two river systems during the 1993 flood in Kansas, USA

W. GEYER, T. CABLE, T. NEPPL and K. BROOKS

ABSTRACT - Streambank changes after the Kansas flood of 1993 were examined using aerial photography to determine the relationship of streambank stability to natural riparian vegetation, stream channel morphology, and soil type. The flooding event that occurred that summer along river courses in the central plains area of the United States was considered in the magnitude of a 100- to 500-year category. Water flooded riverbanks and farmlands for a 2- month period in the summer. Lateral streambank erosion was related significantly to vegetative cover and soil types; erosion was greatest on cropland and minimal on the forested streambanks and greater on sandy than on silty soils. Channel position or the interaction of soils with cover type or channel position influenced lateral erosion on only one river system. The flood was so large that the water flowed over the banks for great distances much of the time, thus masking the dynamic effect of water.

Key words: deposition, erosion, flood, streambank, woodlands

INTRODUCTION

Woody vegetation is recognized as the most effective vegetative type for stabilizing streambanks and reducing erosion under normal stream-flow conditions (TURNER, 1995; WELLS, 1995). Vegetation reduces streambank erosion by slowing stream-flow velocity, by trapping sediments in its stems and foliage, and by binding soil and making it resistant to the erosive forces of water (HICKIN, 1984; MALANSON, 1993).

Some locations along a stream channel are more likely to erode than others. Extensive erosion typically occurs at the outside bend where flow velocities are greatest, whereas along inside bends where velocities are slower, soil particles deposit and form sandbars (MALANSON, 1993). More erosion occurs at the outside apex than any other portion of the stream channel (LEOPOLD *et al.*, 1964; MALANSON, 1993).

This study investigated the influence of woody riparian vegetation and channel position on streambank erosion/deposition during high magnitude flood conditions as compared to past research that examined typical stream-flow conditions.

MATERIALS AND METHODS

Study area. The study area was in the Kansas and Republican River basins, which covers about 15.5 million hectares in three states. The specific zone of study was a 60 and 20 km portions near Manhattan, Kansas at about 39 degrees N latitude and 96 degrees W longitude. The rivers flows eastward through the Central Lowlands Province. Elevation is approximately 400 m. Climate is typical continental with periodic droughts, and mean annual precipitation is about 850 mm in the study area. Natural vegetation generally is mixed mid- and tall- grass prairie. The riparian woody vegetation consists of many deciduous, broadleaf, forest species, including *Populus deltoides, Acer saccharinum, Salix species, Celtis occidentalis,* and *Platanus occidentalis.*

The 1993 flood was devastating to the region. Flooding inundated areas that had not been affected by previous floods. Record, peak, stream-flow discharges were recorded by United States Geological Survey (U.S.G.S.) stream-flow gaging stations throughout the Kansas River Basin.

Tools of investigation. Aerial photographic images (35 mm slides taken in December 1992 and December 1993) were chosen to compare pre- and post flood conditions, because features such as riparian vegetation and streambank edge can be identified easily. Local Consolidated Farm Service Agency (C.F.S.A.) offices provided slide images of the study area.

Data collection process. Photocopies of the slides were digitized with a CalComp digitizing tablet into file format with a LandCADD R12 computer-aided drawing (C.A.D.) program file format. The photocopies were calibrated to previously digitized U.S. Geologic Survey 7.5 minute topographical quadrangle maps to enable accurate scaling and analysis of the images. Only features useful in calibrating slide images, such as roads, railroad tracks, and mile section lines, were digitized from the quadrangle maps. Once the base maps were digitized, streambank edges from the 1992 and 1993 slide images of the Kansas River were digitized. Notes as to land-cover and channel-position conditions were made within the drawing as needed. Then a river centerline was interpolated within the C.A.D. drawing using the 1992 streambanks as guides. The centerline served as a reference line for landcover and channel-position classification and data collection.

Data collection points were established at regular 500-foot intervals along the centerline in the study area. At these points, land-cover and channel position were classified using the 1992 aerial photographs as references. Erosion and deposition amounts were estimated by measuring the perpendicular distance from the 1992 streambank to the 1993 streambank at data collection points. A detailed description of these procedures is found in NEPPL (1996).

Land-cover vegetative types were categorized as: forest land, cropland, grassland, or single-tree row in the 30 m zone next to the 1992 streambank. A forested streambank is one on which the dominant land-cover type (>51%) is woody vegetation. A cropland or

grassland streambank is one on which the dominant land-cover type is either an agricultural crop or grass. Finally, a single-tree row streambank is one on which a single row of trees exists adjacent to a nonforest land-cover type. Channel position was classified as: straight, outside or inside curve.

Data were collected for both the left and right side streambanks and inserted as attributes (a function of C.A.D.) at every data collection point. Attribute information then was extracted from C.A.D. and inserted into the SAS statistical (SAS INSTITUTE INC, 1982) program for analysis.

Analysis of date. Data were collected from a total of 204 (Kansas River) and 256 (Republican River) streambank points. Analysis was conducted by two-way analysis of variance (ANOVA) with factorial designs. Data from each side of the rivers were pooled for analysis.

RESULTS AND DISCUSSION

The data points on the Kansas River were classified as follows: 59% were forest lands, 18% were croplands, 23% were grasslands, and 12% were single-tree rows. Channel positions were classified as follows: 46% points were straight, 32% were outside curves, 22% were inside curves. Data for the Republican River were 96% forested and 4% other; with 50% straight, 29% outside curves, and 21% inside curves.

Results indicate that 99% of the time (P>0.001), land cover affected the amount of erosion of the lateral streambank but not channel position or interaction between the two variables where a large of amount of all cover types were represented (Tab. 1). On the Kansas River both forested and single-tree row vegetation types collected soil with mean depositions of 2.9 m and 0.6 m (not significantly different), respectively, whereas grassland on the average lost 23.9 m and cropland lost 47.2 m (significantly different). Thus, woody vegetation was highly important for protecting streambanks. Because of the large magnitude of the 1993 flood, the water completely covered much of the floodplain rendering channel position unimportant in this analysis. Erosion from a large amount of water contained in the river course likely would have shown the typical pattern of high erosion at the outside curve position and deposition at the inside curve.

On the Republican River cover type did not have an influence as most of the banks were lined with trees. Being a smaller river with less water movement, position did influence the amount of erosion (Tab. 2)

TABLE 1

*Lateral movement of Kansas River streambank by cover type, channel position, and soil type; * Number of observations, ** Values followed by different letters by rows or columns are significantly different at the 5% level (Duncan).*

*Slittamenti laterali delle sponde del fiume Kansas in relazione al tipo di copertura vegetale, alla posizione dei canali ed al tipo di suolo; * Numero di osservazioni, ** Le lettere indicano differenze significative al 5% (Duncan) nei valori medi riportati sia in riga che in colonna.*

Variable	Channel position-lateral distance in ft/m (n)*			
	Straight	Outside curve	Inside curve	Mean **
	Cover type			
Forest	6/2(52)	27/8(25)	18/2(18)	9.5/2.9(95)a
Crop	-84/-26(16)	-229/-70(9)	-192/-59 (10)	-154.7/-47.2(35)c
Grass	-80/-24(21)	-52/-16(13)	-105/-32(13)	-78.4/-23.9(47)b
One tree	-113/-34(3)	51/16(16)	-46/-14(4)	2.0/0.6(23)a
Mean	-3.6/-11.0(92)	-25.4/-7.7(63)	-71.8/-22(45)	-40.8/12.4 (200)
	Soil type			
Sandy	-18/14(25)	-4/1(30)	-42/13(21)	-57.1/-17.4(114)a
Silty	-18/6(33)	-44/14(30)	-42/13(24)	19.1/-5.8(86) b
Mean	-36.1/-11(92)	-25.4/7.7(63)	-71.8/-21.9(45)	-40.8/12.4(86)

TABLE 2

*Lateral movement of Republican River streambank by channel position and soil type; * Number of observations, ** Values followed by different letters by rows or columns are significantly different at the 5% level (Duncan).*

*Slittamenti laterali delle sponde del fiume Republican in relazione alla posizione dei canali ed al tipo di suolo; * Numero di osservazioni, ** Le lettere indicano differenze significative al 5% (Duncan) nei valori medi riportati sia in riga che in colonna.*

Variable	**Channel position: lateral distance in ft/m (n)***			
	Straight	**Outside curve**	**Inside curve**	**Mean ****
Sandy	-10/3(106)	-21/-6(65)	-1/0.3(47)	-11/3(218)a
Silty	-5/-1(227)	-10/-3(10)	17/5(6)	-3/-1(38)b
Mean	-9/-3(128)a	-20/-6(75)b	1/0.3(53)c	-10/-3(256)

straight 2.7 m, inside 0.3 m, and outside 6.0 m significant at the 1% level.

The amount of erosion or deposition in this study did not account for the volume of soil eroded and deposited, as we evaluated lateral streambank movement. However, the authors predict that the volume of soil erosion and deposition would be similar to the results for the extent of streambank movement.

The volume of soil eroded probably was considerably greater than the volume of soil deposited. Sandy soils on both river systems eroded three times greater than the silty soils ($P > 0.033$).

CONCLUSIONS

Woody riparian vegetation has a highly beneficial effect in protecting streambanks, because tree cover did reduce the extent of streambank erosion caused by the flood of 1993. Forested areas on both sides of the river sustained more soil deposition than those areas that had no woody vegetation cover. Channel position did not alter the amount of erosion in the larger river system, because extensive erosion occurred at all channel positions, probably because the entire floodplain was being covered with water.

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RIASSUNTO - Questo lavoro ha esaminato, per mezzo di aereofotogrammi, i cambiamenti delle sponde ripariali avvenute a seguito dell'alluvione del Kansas del 1993, per comprendere le relazioni tra la stabilità delle sponde dei corsi d'acqua e la vegetazione ripariale naturale, la morfologia dei canali ed il tipo di suolo. Questa alluvione, che interessò la pianura centrale degli Stati Uniti, durò circa due mesi. L'erosione laterale delle sponde dei corsi d'acqua fu significativamente correlata al tipo di copertura vegetale ed ai tipi di suolo: l'erosione fu maggiore nelle aree agricole e minima nelle aree forestali, inoltre risultò maggiore nei terreni sabbiosi che nei terreni limosi. La posizione dei canali o l'interazione tra i suoli ed i tipi di copertura vegetale o con la stessa posizione dei canali influenzò l'erosione laterale in un solo sistema fluviale. L'alluvione fu di una tale intensità che interessò per molto tempo larghe estensioni di sponde ripariali, mascherando così gli effetti dinamici dell'acqua.

AUTHORS

W. Geyer, T. Cable, T. Neppl, and K. Brooks, Throckmorton Hall, Kansas State University, Manhattan KS 66506 USA, e-mail: wgeyer@oznet.ksu.edu*

**Corresponding author*

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Hydrological impacts of reforestation with eucalyptus and indigenous species in southern China

G.Y. ZHOU and J.H. YAN

ABSTRACT - Tree growth, climate, litter biomass and understorey cover, throughfall and stemflow, surface runoff, soil erosion, soil moisture and water table depth were monitored over a 10-year period in three catchments in southern China. These three catchments belong to a series of rehabilitating heavily degraded lands, and comprise bare land, eucalyptus plantation and mixed forest. Both forest types ameliorated their microclimate compared to bare land, including increased absolute humidity and reduced maximum temperature near the ground. The mixed forest canopy had higher rainfall interception capacity and generated less stemflow than the eucalyptus forest. Surface runoff was greatest in bare land, and least from mixed forest. Soil erosion of bare land was 5 and 129 times higher than that from the eucalyptus and mixed forest catchments respectively, and contained a higher proportion of coarse sediments. Water table depth averaged 30 cm deeper beneath mixed forest and 80 cm deeper beneath eucalyptus forest, compared with bare land. The results support the use of eucalyptus as a pioneer species in the rehabilitation of degraded lands in southern China, demonstrate the additional hydrological benefit of encouraging succession to a mixed forest ecosystem.

Key words: microclimate, reforestation, soil erosion, soil moisture, stem flow, surface runoff

INTRODUCTION

The origins of reforestation programs in southern China can be traced back to 1950, soon after the creation of the People's Republic of China. Initially the objective of forest establishment on bare and degraded lands was primarily for timber production without consideration of environmental issues, and in some areas serious soil erosion was caused. Since 1975 the emergence of new markets for forest products and increasing awareness of the need for environmental protection and improvement have promoted increased efforts at reforestation with a more complex set of management objectives, in some areas including the restoration of degraded natural ecosystems (CHEN *et al.,* 1995).

Previous studies have shown the importance of water and heat as limiting factors for the rehabilitation of degraded lands in the subtropical area of southern China (JANZEN, 1988; MYERS, 1989; PARHAM, 1993; ZHOU, 1997a). The key problem of vegetation restoration in this region is to ameliorate the degraded environment to allow plant survival and redevelopment of forest ecosystems (MURPHY, LUGO, 1986; BROWN, LUGO, 1994). This requires reduction of runoff and soil erosion, improvement of soil permeability and water storage, increasing atmospheric humidity and limiting solar radiation at the soil surface.

In the sterile environment of severely degraded lands, restoration of original ecosystems requires a multi-step process. The first stage is to establish some pioneer tree species that can survive in the harsh conditions, to make an artificial forest. After improvement of the environment by the artificial forest, some local species can be transplanted to it to further ameliorate the microclimate and soil conditions, creating niches for invasion by further indigenous species. This process has been found effective for rehabilitation of heavily degraded land in China, and recommended for wide application (PARHAM, 1993; YU, 1994, 1995).

Successful selection of pioneer tree species is clearly of critical importance to the success of restoration. In southern China the species adopted include several *Eucalyptus* species, *Pinus massoniana* and *Acacia mangium,* but eucalyptus are of particular importance (YU, 1994, 1995). In addition to an important economic role as a source of construction timber, pulpwood, eucalyptus oil, honey and other products (BAI, GAN, 1996), eucalyptus are widely planted for ecological values including that of pioneer species for rehabilitation of degraded ecosystems (YU, 1994, 1995; MIDGLEY, PINYOPUSARERK, 1996) and as typhoon shelter for crops and villages (TURNBULL, 1981; BAI, GAN, 1996).

The success of eucalyptus as pioneer species arises from their capacity for vigorous growth and deep rooting on sites of low fertility. However, strong competition for water and other resources may limit subsequent success in establishing indigenous trees and understorey species under the eucalypt canopy, and prevent natural succession beyond a eucalypt dominated community. The ability to compete successfully on water-limited sites has raised concern that excessive water consumption by eucalypt plantations may deplete water supplies by reduction of runoff and groundwater recharge, in China and elsewhere (KALLARACKAL, 1992). Surface and underground water resources in southern China are often limited in spite of the moderately high annual rainfall of the region (ZHOU, 1997b), due to loss of high intensity rainfall during the wet season as surface runoff with concomitant problems of erosion, siltation and flooding (CHEN, WANG, 1992; PARHAM, 1993). During the dry season, groundwater bores are an important source of water for domestic, agricultural and manufacturing uses. Water shortage during this period limits both the capacity for production of crops, and the capacity for urban development.

This paper examines the impacts of reforestation on environmental conditions in a degraded area of coastal western Guangdong province. Reforestation there since 1959 has created a range of artificial ecosystem types, from the original degraded land, through economic plantations of *Eucalyptus exserta* and *Pinus massoniana,* to artificially developed mixed forest. These vegetation types may be seen as representing different stages of succession (GUEVARA *et al.*, 1986), and their amelioration of the water and heat environment are related to the success of rehabilitation. Studies of the effects of vegetation on environment have focussed on a comparison of hydrology and microclimate in *E. exserta* plantation, bare land and subtropical mixed forest.

MATERIALS AND METHODS

The study area

The studies were conducted in three experimental watersheds located on coastal highland near Xiaoliang in Dianbai County, Guangdong Province (21° 8′ N, 110° 54′ E). Mean annual rainfall in the region was 1455 mm in 1981-1990, with distinct dry (October to March) and wet (April to September) seasons. Total rainfall during the dry and wet seasons was 17% and 83% of the annual total, respectively. Rainfall in the region is mainly associated with convectional storms and typhoons, and the intensity often exceeds 16 mm h^{-1}. The annual average temperature is 23° C. The soil is a typical laterite derived from granite (YU, ZHOU, 1996). The topography of the three watersheds is generally of low relief, with altitude variations of 10 to 20 m.

The bare soil watershed (area 3.7 ha) had been virtually devoid of vegetation for at least four decades before reforestation efforts began in 1959 because of severe soil erosion. This watershed has been maintained as a control for studies of environmental amelioration in the surrounding area.

The *Eucalyptus* (*E. exserta*) plantation watershed (3.8 ha) was established in 1964. Before that time, its surface was also totally bare and eroded, and its soil chemical and physical properties were similar to those of the control catchment (PARHAM, 1993; YU, 1994; YU, ZHOU, 1996). The eucalyptus forest grew vigorously until 1972 and more slowly thereafter. In 1976 the plantation was harvested, with branches and leaves left on the site. The plantation was regenerated by coppice regrowth on the cut stumps followed by thinning to leave single stems at a spacing of 2.5 x 2.5 m. By 1990, light attenuation by the eucalyptus canopy was 76% and average tree height was 13 m, with 90% of trees between 12.7 and 13.5 m. No understorey developed under the growing forest, due to repeated disturbance and intensive removal of forest litter by local residents for fuel. In 1986, a section of the plantation (1536 m^2) was fenced off to limit access and prevent litter removal, while the rest of the area remained open as before (Fig. 1). By 1994, the understorey cover rate (average ratio of understorey canopy area to ground area) was about 65% on the protected area, with averaged height of 1.5 m. The third watershed (6.4 ha) was also initially established as *E. exserta* plantation, similar to that described above. In 1975 the plantation was thinned to 400 trees per hectare and indigenous species were planted at irregular spacing over the whole catchment. The species include *Aphanamixis polystachya, Cassia siamea, Albizia odoratissima, Aquilaria sinensis, Santalum album, Leucaena leucocephala* cv. Salvador and *Acacia auriculaeformis.*

A topographical map of the area including the three catchments is shown in Fig. 1.

Climate

A weather station was installed in each catchment and in the protected area, on a tower extending 4 m above the canopy. For mixed forest catchment, an observation tower with the top 4 m above the canopy was erected. Measurements of radiation, (including gross, net and reflected radiation), rainfall, wind speed and direction, relative humidity and air temperature were recorded daily at 0800, 1400 and 2000. Similar measurements (except for rainfall) were collected at 1.5 m above ground, and soil temperature was measured near the base of each tower at depths of 0 cm, 5 cm, 10 cm, 15 cm and 20 cm. In all three catchments, hourly climate observations were also collected continuously over 24 hours for 2 or 3 days of each month.

Surface flow and soil erosion

The runoff from all three catchments was monitored by measurement weirs with stream flow recorders on the ephemeral streams emanating from each and recorded automatically for every precipitation event during 1981-1990. A separate monitored subcatchment (1536 m^2) was set up in 1986 for the protect-

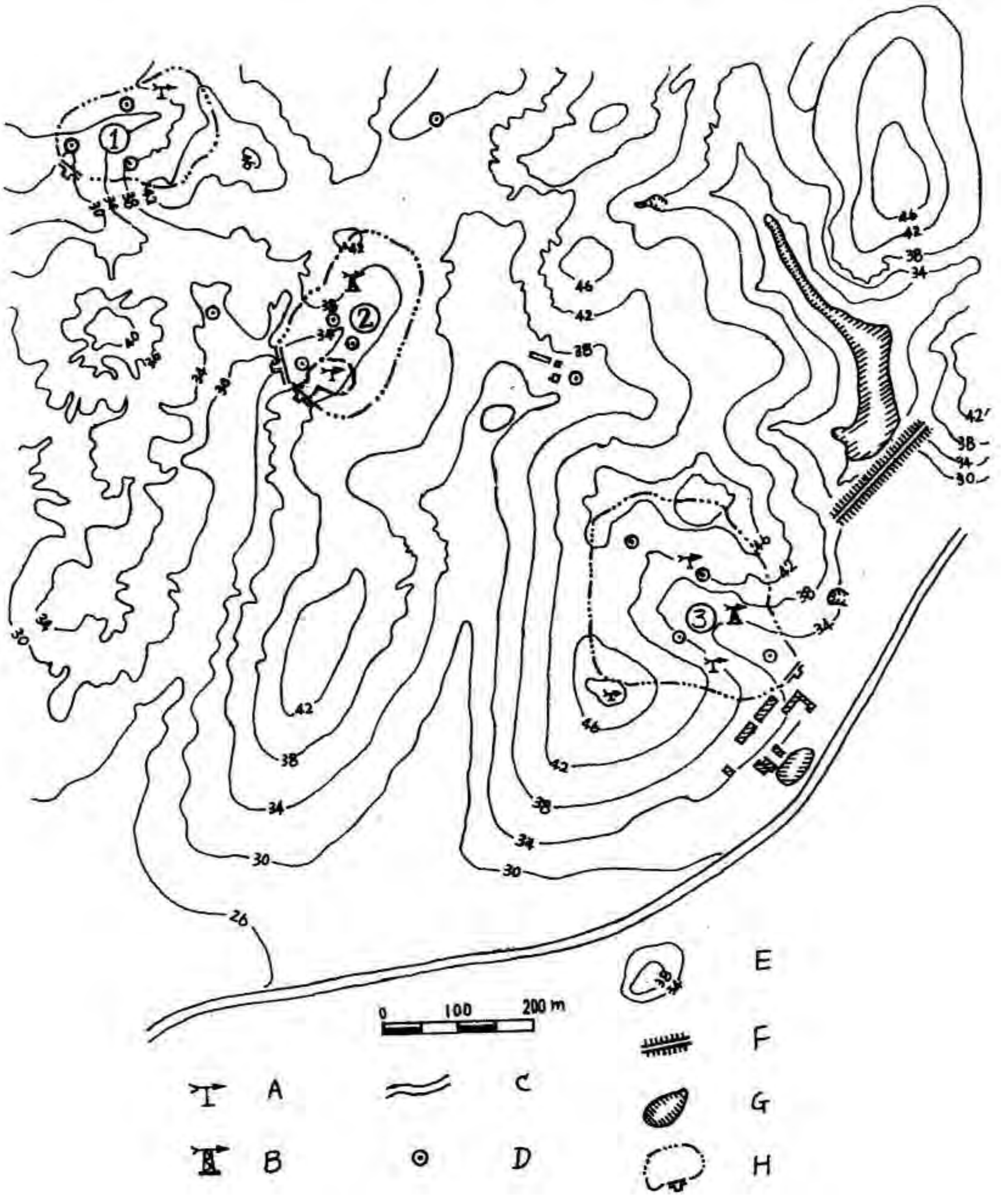

Fig. 1
Topographical map of the Xiaoliang experimental area. ③ Bare land catchment; ② Eucalyptus catchment; ♣ Mixed forest catchment; A: Meteorologic measurement point; B: Observation tower; C: Highway; D: Water table observation well; E: Contour; F: Dam; G: Reservoir; H: boundary and outlet weir of catchment or subcatchment.
Mappa topografica dell'area sperimentale di Xiaoliang. ③ suolo nudo; ② foresta di eucalipto; ♣ foresta mista; A: stazione meteorologica; B: torre di osservazione; C: autostrada; D: pozzetto di controllo del livello di falda; E: curve di livello; F: diga; G: bacino di riserva; H: delimitazioni degli sbarramenti con relativi sbocchi dei bacini o sub-bacini imbriferi.

ed area, using a ditch to lead the runoff out of the catchment. The recorded water flow over each weir in liters was divided by the catchment area in m^2 to express runoff in mm. A surface runoff coefficient was calculated as surface flow (mm)/precipitation (mm) X 100%.
The amount of storm flow in runoff from a rain event is an important indicator of the hydrological effectiveness of forest cover and is also important as a key cause of soil erosion (LINSLEY, 1975; SINGH, 1988). Hydrographs for each precipitation event were used to estimate the amount of storm flow following LINSLEY (1975). Storm flow in mm was expressed as a percentage of incident rainfall for each catchment.
Soil removed from the catchments in surface runoff was assessed separately as suspended solids and bed load (SINGH, 1988; ZHOU *et al.*, 1995; YU, ZHOU,

1996). Bed load was deposited in a pool located upstream of each weir, and was measured manually by weighing soil dredged from the pool after each rainfall event. Suspended solids were determined as the product of runoff volume and concentration of suspended solids for each rain event. In each month, at least one rain event was selected to sample for determination of suspended solids concentration. Three 1 litre samples (beginning, peak stage and ending) were taken during the rain event and combined, then filtered to determine the weight of suspended solids in the runoff. It was assumed that the value would be the same for all runoff in a month. Soil erosion rates were characterized as kg of suspended and deposited sediment per unit of catchment area, per mm of rainfall (kg ha^{-1} mm^{-1}).

Soil and groundwater measurements

Because the topography of the area generally has low relief and the forest was uniform for the two forest catchments, only three locations were selected for soil monitoring in each catchment, located in upper, middle and low slope positions. From 1986, an additional location was selected within the protected area of the Eucalyptus catchment.

At each location soil bulk density was measured at three depths (0-15 cm, 60-80 cm and >120 cm) using a steel cylinder of 80 mm diameter, once each year in October from 1981 to 1990. Soil water content was initially determined gravimetrically on samples collected at 10 cm depth intervals to 200 cm in depth, once per month during 1981-1985. From 1986, soil water content was measured by neutron probe. Three groundwater monitoring wells were installed in each catchment, again located in upper, middle and lower slope positions. Watertable depth was manually recorded at intervals of 5 days and averaged for each month.

Throughfall and stemflow monitoring

Throughfall in the forested catchments was collected by a single trough with a horizontal area of 6 m^2. Water gathered by the trough was channelled to a V-shaped outlet and a fluviograph was used to record the water level in the outlet channel (ZHOU, 1997). Because the *E. exserta* trees were evenly spaced, and both the mixed forest canopy and eucalyptus canopy were uniform, a single trough in each catchment was considered sufficient to sample throughfall (GASH, 1978; VERTESSY, 1993).

Ten trees adjacent to each site where through fall was monitored were selected for stem flow measurement (GASH, 1978; LEE, 1980), spanning the range of diameters of the whole plantation. For the mixed forest, nine species of trees of average diameter were selected. They were *Eucalyptus exserta* (two trees), *Aphanamixis polystachya, Cassia siamea, Albizia odoratissima, Aquilaria sinensis, Santalum album, Leucaena leucocephala* cv. salvador, *Acacia auriculaeformis,* and *Pinus massoniana*. Stem flow was collected by an open PVC tube wrapped around the stem, and led to a tipping bucket rain gauge. The average stem flow for each stand was calculated from the data recorded by the rain gauges as:

S_c: stand stemflow (mm); A_g: area of a rain gauge (m^2); A_{ci}: canopy projected area of tree number i (m^2); S_{mi}: recorded data for rain gauge number i (mm).

$$P_s = \frac{A_g}{\sum_{i=1}^{10} A_{ci}} \times \sum_{i=1}^{10} S_{mi}$$

Litter biomass and understorey cover

From 1986 on, litter accumulation and understorey cover were assessed at two year intervals in the protected area of the Eucalyptus catchment. Litter was collected from ten plots each 1 m X 1 m square, then dried and weighed. At the same time, the understorey cover percentage of the whole area was visually estimated.

RESULTS

Seasonal variation in rainfall and solar radiation

Monthly means of net radiation and rainfall over 10 years (1981-1990) are shown in Fig. 2. Wet season rainfall in the study area is 82.9% of the total, while radiation during the same period is 65.8% of the annual total. Prolonged warm dry conditions during the dry season may promote soil crusting, increasing runoff and rendering the soil surface susceptible to erosion by rainstorms in the following wet season.

Temperature and humidity near the soil surface

Fig. 3 shows daily mean soil and air temperatures at several levels above and below the soil surface, averaged over ten years of observations (1981-1990) for the three catchments and over four years (1986-1990) for the protected area of the eucalyptus catchment.

Temperatures in the bare land catchment were highest at all times of the year, and those in the eucalyptus catchment unprotected area (UA) were usually lowest. Temperatures in the mixed forest were similar to those of bare land in the dry season, but similar to the eucalyptus catchment UA in the wet season. Thus the mixed forest had the least temperature variation, with relatively warm winter temperatures and cool summer temperatures. In all catchments, air temperature decreased continuously from ground level to 1.5 m above the surface, with the greatest decrease between 0 and 0.2 m, which may imply that proximity to the land surface influences temperatures within this zone. The only exception is in July over bare land, when temperature was elevated within 0.5 m above the land surface.

The decrease in temperature with height above the surface was accompanied by a tendency for relative humidity (RH) to increase with height. RH was always higher in the mixed forest than in the eucalyptus UA and bare land catchments, and varied less between seasons. The pattern of RH variation with height above the surface may result from variations in both temperature and absolute humidity.

Absolute humidity (AH) (g m^{-3}), calculated from the

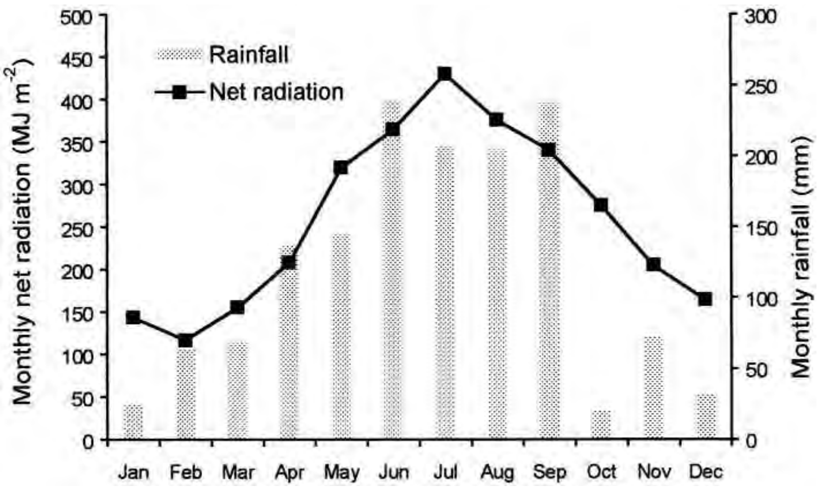

Fig. 2
Monthly distribution of rainfall and net solar radiation averaged over ten years at Xiaoliang.
Medie decennali mensili delle precipitazioni e della radiazione solare netta in Xiaoliang.

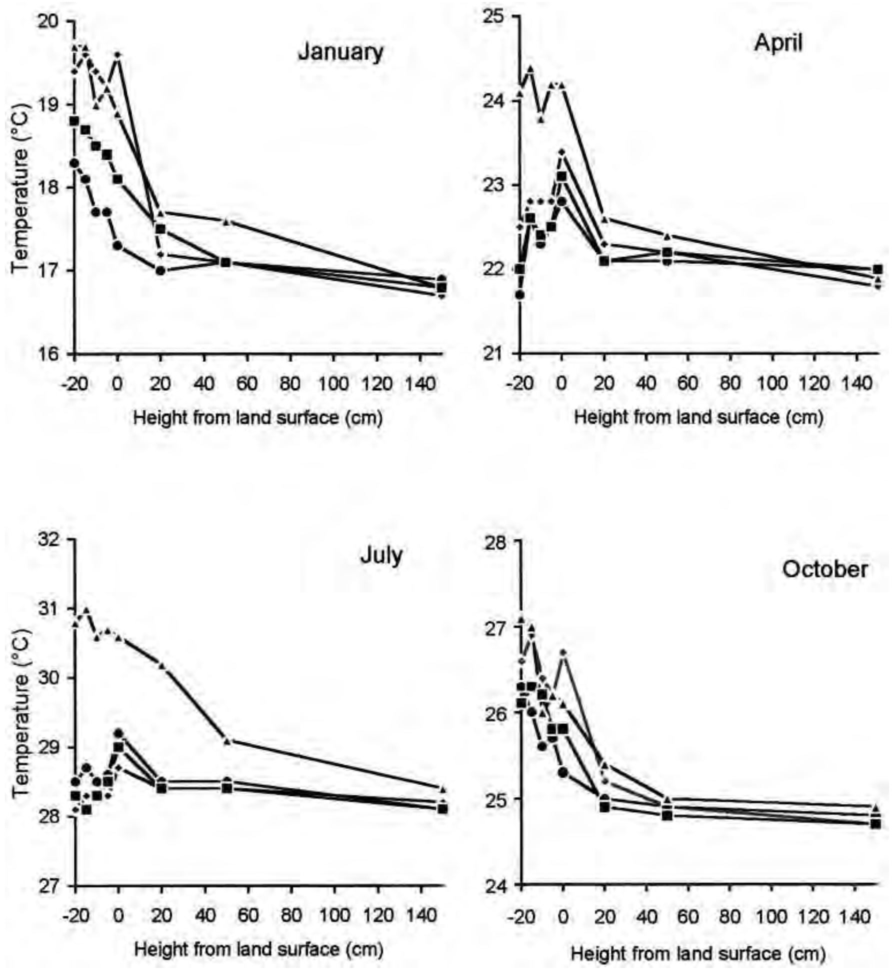

Fig. 3
Daytime mean temperature measured near the soil surface in the three catchments. —♦— Mixed forest; —●— Eucalyptus plantation (unprotected); —■— Eucalyptus plantation (protected); —▲— Bare land.
Temperature medie diurne misurate a diverse altezze dalla superficie del terreno nei tre bacini imbriferi. —♦— Foresta mista; —●— piantagioni non protette di eucalipto; —■— piantagioni protette di eucalipto; —▲— suolo nudo.

observations of mean air temperature and relative humidity (%), varied with height above the soil surface for the four experimental sites (Fig. 4). AH in bare land decreased continuously with height in all seasons, especially in July and April. In the vegetated catchments AH tended to reach a maximum at about 0.5 m above the surface.

Throughfall and stemflow

The interception of rainfall by the forest canopy (I, mm) was found to be closely related to the rainfall of a rain event (R, mm). The best-fit regression equations are:

$I = 0.65\ R^{0.55}$ ($n = 378$ and $r > 0.96$), for eucalyptus forest

$I = 0.75\ R^{0.61}$ ($n = 413$ and $r > 0.90$), for mixed forest.

Stem flow (P_S in mm) was also closely related to R (mm), and the best-fit regression equations are:

$P_S = 0.083\ R - 0.046$ ($n = 266$ and $r > 0.92$), for eucalyptus trees $P_S = 0.068\ R - 0.066$ ($n = 335$ and $r > 0.88$), for mixed forest trees.

The results show the mixed forest has higher interception and less stem flow than the eucalyptus forest (Fig. 5). Considering that the recorded historic maximum rainfall in a rain event was less than 100 mm (ZHOU, 1997a), the maximum interception capacity of the two forest types is approximately 8 mm and 12 mm in a rain event for eucalyptus and mixed forests, respectively. The stem flow results also reflect the higher interception capacity of the mixed forest. Stem flow occurred in the eucalyptus forest when rainfall exceeded approximately 0.6 mm, but the corresponding minimum rainfall for stem flow in the mixed forest was 1.3 mm.

Surface runoff

Surface runoff differed considerably among the three catchments. Tab. 1 shows monthly surface flow coefficients based on rainfall and runoff observations from 958 rainfall events between 1981 and 1990. For the eucalyptus catchment, runoff data are from the unprotected site. Surface runoff from the bare land catchment was greatest, followed by the eucalyptus catchment while runoff from the mixed forest was very low. These results reflect qualitative differences in the condition of the soil surface and vegetation cover. The mixed forest had a well-developed understorey with three or more layers of vegetation. Differences in aspect and topography among the

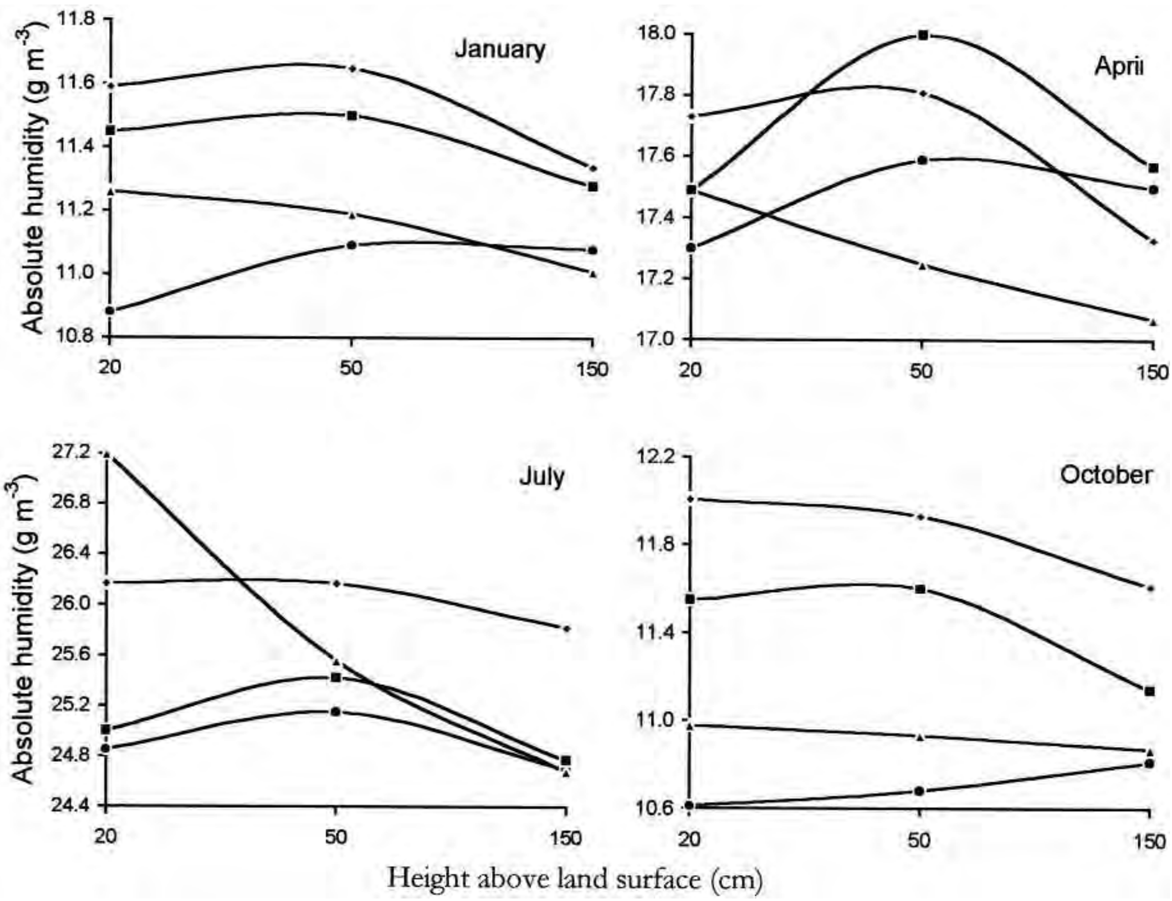

Fig. 4

Daytime mean absolute humidity at 20 to 150 cm above the land surface in the three catchments. —♦— Mixed forest; —●— Eucalyptus plantation (unprotected); —■— Eucalyptus plantation (protected); —▲— Bare land.

Medie diurne di umidità assoluta misurata a 20, 50 e 150 cm dalla superficie del suolo nei tre bacini imbriferi. —♦— Foresta mista; —●— piantagioni non protette di eucalipto; —■— piantagioni protette di eucalipto; —▲— suolo nudo.

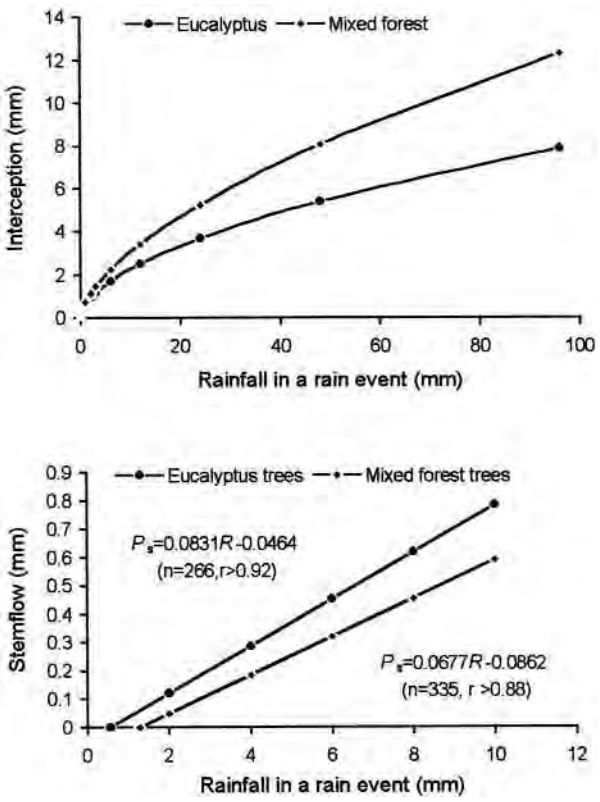

Fig. 5
Interception and stem flow in a rain event for mixed and eucalyptus forests.
Intercettazione della pioggia e *stemflow* in relazione all'intensità delle precipitazioni nelle foreste miste e nelle foreste di eucalipto.

catchments may have also contributed to the difference in runoff (Fig. 1).
Surface runoff coefficients from mixed forest and eucalyptus forest decreased over the period 1981-1990. There was no consistent trend in the annual values of surface runoff from the bare land catchment, but surface runoff from bare land varied in proportion to the yearly rainfall distribution.
Storm flow was highest from bare land, averaging 8.7% of annual rainfall (20.4% of total runoff). That from the eucalyptus catchment was 5.8% (27.1% of runoff), while the lowest storm flow was from mixed forest at 0.02% of rainfall (0.9% of runoff).
Within the protected area of the eucalyptus plantation, surface runoff decreased during 1986-1994 (Tab. 2) as litter accumulated and understorey cover increased. When the protected area was enclosed in 1986, the runoff there was higher than the average over the whole eucalyptus catchment due to local effects of slope and soil surface crusting. The annual average runoff coefficients of protected and unprotected parts in1986 were 33.1% and 15.0%, respectively. By 1994 the surface runoff coefficient in the protected area had fallen to 8.6%.

Soil erosion

Tab. 3 shows the annual erosion rate from the three catchments in 1981-1990. Over the ten year period, the average erosion rate for the mixed forest catchment was 0.3 kg ha^{-1} mm^{-1} of rainfall, including 0.2 kg ha^{-1} mm^{-1} as suspended sediment and 0.1 kg ha^{-1} mm^{-1} deposited at the weir. In the eucalyptus catchment (UA), the erosion rate was 9.1 kg ha^{-1} mm^{-1}, including 5.3 kg ha^{-1} mm^{-1} suspended and 3.8 kg ha^{-1} mm^{-1} deposited sediments. In the bare land catchment, the corresponding rates were 43.7 kg ha^{-1} mm^{-1}, 19.3 kg ha^{-1} mm^{-1} and 24.4 kg ha^{-1} mm^{-1}. The ratios of suspended to deposited sediments were 1.5, 1.4 and 0.7 for mixed forest, eucalyptus (UA) and bare land catchments, respectively, demonstrating the effectiveness of forest cover not only in decreasing the total soil erosion, but also in reducing the proportion of larger sediments removed and deposited in the stream channel.

Soil moisture

Fig. 6 shows soil profile moisture content at 10 cm depth intervals, averaged from all measured values for each point over the study period. In the upper 80 cm, soil water contents for the three catchments were generally similar. Below this depth soil water content in the bare land increased with depth, but in the vegetated catchments it was constant or decreased with depth to 195 cm.

TABLE 1
Mean monthly surface flow and runoff coefficients for the three catchments (1981-1990).
Medie mensili di scorrimento superficiale e relative percentuali nei tre diversi bacini imbriferi (1981-1990).

	Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Full Year
Mixed forest	(mm)	0.0	0.0	0.2	0.4	0.7	14.4	6.8	18.3	1.2	0.0	0.0	0.0	42.0
	(%)	0.0	0.0	0.3	0.3	0.5	6.0	3.3	8.9	0.5	0.0	0.0	0.0	2.9
Eucalyptus	(mm)	2.9	7.0	16.1	27.7	42.9	77.3	53.6	50.0	42.6	4.1	6.7	0.0	330.9
	(%)	11.4	10.9	23.0	20.2	29.4	32.2	25.9	23.9	17.9	19.5	9.2	0.0	23.1
Bare land	(mm)	7.42	23.7	39.7	44.1	91.3	143.5	125.2	121.4	124.2	10.0	7.4	2.3	740.2
	(%)	31.3	37.0	56.7	32.2	62.5	59.7	60.5	59.2	52.2	47.4	10.1	7.1	50.8

TABLE 2
Monthly surface runoff coefficient (%) from the protected area of the eucalyptus catchment.
Percentuali mensili di scorrimento superficiale nelle piantagioni protette di eucalipto.

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Mean
1988	25.4	22.1	30.5	31.3	45.7	42.8	50.4	46.6	48.0	24.3	5.3	2.1	31.2
1990	22.3	18.4	28.7	35.6	42.5	36.4	41.7	33.0	40.0	12.2	2.5	1.3	26.2
1992	10.2	9.8	16.6	22.3	25.7	24.0	27.7	21.6	30.1	4.3	1.0	0.4	16.1
1994	6.3	3.8	9.6	11.4	12.9	13.8	14.5	13.0	15.5	2.1	0.5	0.0	8.6

TABLE 3
Erosion rate of the three catchments in different years (kg ha^{-1} mm^{-1}).
Tassi di erosione nei tre bacini imbriferi (kg ha^{-1} mm^{-1}).

Year		1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Mixed forest	suspended	0.34	0.21	0.02	0.50	1.25	0.00	0.00	0.00	0.00	0.00
	deposited	0.52	0.08	0.01	0.45	0.00	0.00	0.00	0.00	0.00	0.00
	total	0.86	0.30	0.03	0.95	1.25	0.00	0.00	0.00	0.00	0.00
Eucalyptus forest	suspended	6.37	5.64	5.87	5.57	6.94	5.76	4.28	1.93	6.52	4.33
	deposited	4.56	3.90	2.58	3.32	4.79	5.08	5.64	2.77	1.74	3.73
	total	10.93	9.54	8.45	8.89	11.74	10.83	9.92	4.70	8.26	8.06
	suspended	19.32	15.27	14.61	17.71	24.61	19.78	29.83	18.47	14.30	19.00
Bare land	deposited	20.54	13.01	12.94	13.98	58.66	24.93	24.80	18.66	27.36	28.77
	total	39.86	28.28	27.54	31.69	83.26	44.71	54.64	37.13	41.66	47.77

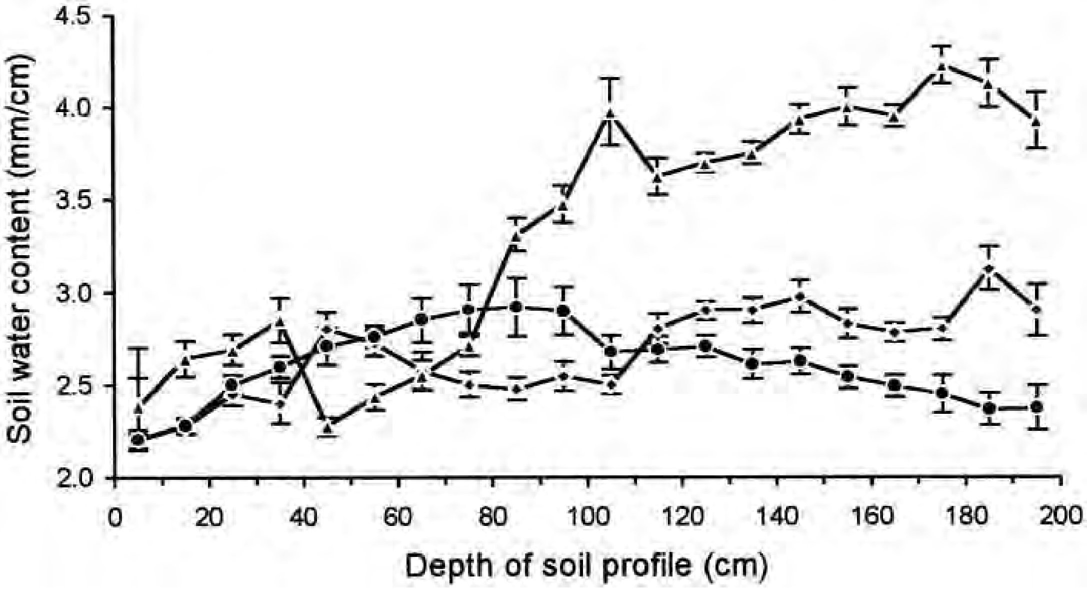

Fig. 6
Soil water content throughout the profile, averaged over 10 years of monthly observation. —♦— Mixed forest; —●— Eucalyptus plantation (UA); —▲— Bare land. Bars indicate ±1 standard error.
Medie decennali mensili dei profili di contenuto idrico del suolo. —♦— Foresta mista; —●— piantagioni di eucalipto (UA); —▲— suolo nudo. Le barre indicano ±1 errore standard.

Soil water content in the eucalyptus plantation reached a maximum at 95 cm depth then declined continuously, suggesting that *E. exserta* may absorb water from deeper in the profile than the mixed forest. A zone of lower soil water content existed in mixed forest at 45-115 cm depth, possibly corresponding to the zone of greatest root density and water uptake (YU, 1995). In the bare land catchment soil water content was always higher than the two forested catchments, but there was little difference between eucalyptus and mixed forest. The average soil water content in the wet season were 2.9 mm cm^{-1}, 2.9 mm cm^{-1} and 3.2 mm cm^{-1} for mixed forest, eucalyptus plantation (UA) and bare land, respectively. Corresponding values in the dry season were 2.6 mm cm^{-1}, 2.6 mm cm^{-1} and 3.0 mm cm^{-1}. No long term trend was apparent in the annual average profile water content of any of the catchments. Soil water content in the protected eucalypt plantation did not differ significantly from that of the unprotected plantation during the period 1986-1994.

Locations of the watertable observation wells for each catchment are shown in Fig. 1. Their relative levels (m above datum) and average watertable depths during 1983-1989 are listed in Tab. 4. The depth of groundwater increases with increasing altitude, indicating a relatively flat watertable reflecting high subsoil hydraulic conductivity. The average watertable levels over three wells in each catchment through the whole period were 29.6 m, 28.8 m and 29.3 m for bare land, eucalyptus and mixed forests, respectively. Relative to the bare land catchment therefore, the mixed forest lowered the watertable by 30 cm and the eucalyptus forest lowered it by 80 cm as an average over the 7 year period of observation.

Variation in watertable depth between wet and dry seasons was greatest in the bare land catchment and least in the eucalyptus plantation. In all three catchments, the highest watertable level was reached in August-September.

Watertables generally declined during the measurement period (1983-1989), but high rainfall in 1985 (2210 mm, compared with an average of 1455 mm for 1981-1990) raised the watertable by up to 1 m in all catchments in that year. The change in annual mean watertable depth over the seven year period did not differ significantly between catchments.

DISCUSSION AND CONCLUSIONS

The coastal region of southern China is subject to a monsoonal climate characterized by distinct wet and dry seasons. Adequate rainfall and relatively warm conditions providing high radiant energy input throughout the year can enable very high productivity from well developed ecosystems in this region (MECINA, 1982; PENG, ZHANG,1995). However, due to the limited capacity of degraded ecosystems to regulate their environment, warm conditions during the season of low rainfall can also make degraded lands more sterile (PARHAM, 1993; BROWN, LUGO, 1994). In the wet season in southern China, storms often cause flooding and heavy soil erosion from bare land, but warm conditions in the dry season may restrict plant survival (ZHOU, 1997). Thus, rehabilitation of barren degraded land there must be a stepwise process (YU, 1994, 1995).

Both the eucalyptus and mixed forest were found to regulate their microclimate, including the air temperature and humidity near the ground. In all three catchments, air temperature decreased continuously from ground level to 1.5 m above the surface, with the greatest decrease between 0 and 0.2 m. The findings of MURPHY, LUGO (1986) similarly suggest an influence of proximity to the land surface extending to this height. Absolute humidity in vegetated catchments reached a maximum at about 0.5 m above the

TABLE 4
Average water table depths for the three catchments during 1983-1989.
Profondità media della falda nei tre bacini imbriferi durante il periodo 1983-1989.

Catchment	Well	Altitude (m)	Average depth, 1983-1989 (m)	Relative level of watertable (m)	Mean relative watertable level (m)
	1	30	0.8	29.2	
Bare land	2	36	6.2	29.8	29.6
	3	38	8.1	29.9	
	1	32	3.5	28.5	
Eucalyptus forest	2	36	7.0	29.0	28.8
	3	36	7.1	28.9	
	1	32	3.2	28.8	
Mixed forest	2	38	8.7	29.3	29.3
	3	44	14.2	29.8	

surface, which may be attributed to evapotranspiration from the understorey. In the unprotected part of the eucalyptus catchment where no understorey existed, this characteristic was less apparent, while absolute humidity above bare land decreased continuously with height.

Because there was no pre-planting calibration period of stream flow monitoring in the three catchments, the quantitative comparisons of runoff and erosion between catchments are subject to an unknown bias. However, the study design is considered adequate for the purpose of quantifying runoff and erosion from individual catchments and identifying qualitative differences in catchment behavior. Surface runoff differed greatly between the catchments, confirming results reported by CHEN, WANG (1992) from work in a neighboring experimental region. The surface runoff coefficients for both mixed and eucalyptus (UA) forests decreased over the period 1981-1990, while the coefficient for bare land showed no such trend. Understorey and litter have been shown by many studies to play an important role in reducing surface runoff (LINSLEY, 1975; SINGH, 1988; MYERS, 1989; VERTESSY, 1993; YU, ZHOU, 1996). In the protected area of the eucalyptus catchment at Xiaoliang, litter biomass and understorey cover increased over a period of 8 years while the surface runoff coefficient decreased continuously.

Storm flow is recognized as a potential damaging agency for ecosystems (LINSLEY, 1975; SINGH, 1988). Stormflow from the eucalyptus catchment as a percentage of rainfall was less than from the bare land, but still considerably more than from the mixed forest catchment with a developed understorey and litter layer.

Although the eucalyptus alone had some positive effects on reducing storm flow, it is clear that the rehabilitation process for degraded lands must extend beyond this pioneer phase to be fully effective.

Associated with the differences in surface runoff and storm flow, there were large differences in soil erosion among the three catchments. The mean erosion rate from bare land was 5 and 129 times that from eucalyptus and mixed forest catchments, and the ratio of suspended to deposited sediments from bare land was only half the corresponding ratio from vegetated catchments. This implies higher kinetic energy of runoff from bare land, to erode and transport the coarser grained materials deposited in the bottom of the stream channel.

Soil moisture content in bare land was higher than in the two vegetated catchments. This may be attributed to water uptake by plant roots, but the soil moisture observations provide no evidence of a difference in water consumption between mixed forest and eucalyptus. There was no long term trend in the annual average profile water content of any of the catchments over a period of ten years.

The water table level in all three catchments generally decreased over the period of observation. Mean water table level in the mixed forest catchment was 30 cm lower than the bare land, and in the eucalyptus catchment was 80 cm lower than bare land. These observations may reflect differences in water uptake by the two vegetation types as well as differences in surface runoff between vegetated and bare catchments.

Our results support the use of eucalyptus as a pioneer species in the rehabilitation of degraded lands in southern China, but demonstrate the importance of allowing litter accumulation and understorey development beneath the tree canopy. Artificially accelerating succession beyond a eucalyptus monoculture by the introduction of indigenous tree and shrub species has been successful at Xiaoliang, with positive hydrological impacts including major reductions in storm runoff and erosion.

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RIASSUNTO - In questo lavoro si è studiato la crescita degli alberi, il clima, la biomassa della lettiera e del sottobosco, *throughfall* e *stemflow*, lo scorrimento superficiale, l'erosione del suolo, il contenuto idrico del suolo e la profondità della falda, in tre diversi bacini imbriferi (suolo nudo, piantagione di eucalipto e foresta mista) ubicati nel sud della Cina durante un periodo di 10 anni. Il microclima di entrambi i tipi di foresta è risultato migliore di quello del suolo nudo, in termini di più elevata umidità assoluta e più bassa temperatura massima misurata a livello del suolo. La foresta mista ha mostrato una maggiore capacità d'intercettazione delle precipitazioni ed ha generato un minore *stemflow* rispetto alla foresta di eucalipto. I valori maggiori di scorrimento superficiale si sono verificati sul suolo nudo, mentre quelli più bassi si sono riscontrati nella foresta mista. Di conseguenza l'erosione del suolo nudo è risultata pari a circa 5 volte quella registrata nella foresta di eucalipto ed a circa 129 volte quella della foresta mista. Inoltre nelle foreste di eucalipto e nelle foreste miste la falda è risultata essere in media più profonda rispettivamente di 30 e 80 cm rispetto a quella presente nel suolo nudo. Dai risultati ottenuti emerge il ruolo positivo svolto dall'eucalipto come specie pioniera nella riabilitazione dei territori degradati nella Cina del sud, ma soprattutto risaltano i benefici idrologici aggiuntivi derivanti dalla successione agli ecosistemi forestali misti.

AUTHORS

G.Y. Zhou, J.H. Yan, South China Institute of Botany, Chinese Academy of Sciences, Guangzhou 510650, China

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The current situation and development tendency of Chinese timber market under the policy of conservation natural forest

D.G. CAI and Z.Y. LI

ABSTRACT - It was essential to protect the limited natural forest resource in China by enforcing the policy on prohibiting cutting natural forest and quota logging, which was made in 1998 and implemented in 1999 by the government of China. The policy analysis of current situation and tendency of Chinese timber market shows that, with the rapid and continuous economic development of China, and the further opening of timber market, the timber market of China will have the development tendency of diversity, multi-elements in market structure, new products selling well, co-flourishing of supply and demand. This will provide, to a certain extent, a good market circumstance for the conservation of natural forest and environment construction in China.

Key words: conservation of natural forest, forestry policy, timber market

INTRODUCTION

As a kind of renewable resource, the effective conservation and rational utility of forestry resource was a matter we could not avoid (ABARE, 1999). Because of limited supply of timber from natural forest, increasing market demand for timber in China, in the entry of the 21st century, much attention should be paid on the study of the current development situation and tendency of Chinese timber market, taking counter-measures as soon as possible to protect scarce natural forest and improve fragile environment (JIANG, CAI, 1997).

Since the establishment of P.R.C., the timber market of China has undergone two different stages during the period of over fifty years. The former was the planned economy stage. It ended in 1978 when China took reformation and open policy. The basic features of that stage were that the timber supply was based on strict plan, took self-sufficiency as the main goal, 90% of commercial timber was from natural forest, the waste and destruction of forestry resources were serious (Tab. 1). Since the reformation and opening, there was a transition period during which the timber market of China turned into socialism market economy. The primary features were that it was regulated by market forces, supplying the lack by import, the amount and quality of home timber decreased year by year, while the scale and value of imported timber increased. In view of the develop-

TABLE 1
Production scale and market demand quantity of inside-state plan timber (Unit: ten thousand cubic meters).
Scala produttiva ed ammontare della domanda di mercato interna di legno (unità: diecimila metri cubici).

Year	Actual production (A)	Market demand quantity (B)	Difference (AB)
1965	3302	3210	92
1970	3259	3413	-159
1975	4034	4120	-86
1985	5833	6181	-348
1990	5109	5756	-647
1992	5627	6405	-778

ment level and tendency of Chinese timber market, the government of China executed in 1999 the strict policy on prohibition and quota logging of natural forest, which almost shut off the supply source of natural timber in Chinese timber market. With the rapid and continuous economic development of China, the further opening of timber market, the timber market of China will show the development tendency of divers market, multi-elements in market structure, new products selling well, co-flourishing of supply and demand. This will provide, to a certain extent, a good market circumstance for the conservation of natural forest and environment construction in China (LIN, 2000).

THE CURRENT DEVELOPMENT SITUATION OF CHINESE TIMBER MARKET

In 2000, the State Forestry Administration published the results of the fifth national forestry resource inventory (1994-1998). It was indicated that the area of national forest land was 263.295 million ha, the area of forest was 158.941 million ha, the standing stock was 12.49 billion cubic meter, the forest stock was 11.27 billion cubic meter, and the forest coverage was 16.55%. The area of national plantation was 46.667 million ha, and the stock of plantation was 1.01 billion cubic meters. The plantation area of China took the first place in the world. Compared with the fourth forestry resource inventory, the forestry resource condition improved substantially. It realized the simultaneous increase of forest area and stock, so did the forest coverage.

However, China still lack forests. Moreover, despite the area and stock of forest resource of China was not poor, their distribution was not balanced, their structure was irrational, and their quality decreased to some extent (LI, 1996). Especially the proportion of climax and over mature forest in natural commercial timber forest appeared in downtrend. This inevitably influenced the Chinese timber market (Tab. 2).

Before the 1970s', the Chinese economy was self-sufficiency and consequently, the volume of trade was very small. Since the 1980s, with the implementation of reformation and open policy, the economic restructuring came to a rapid increase. Meanwhile, because of the increase of the population and decrease of home forestry resource, the original sharp contradiction between supply and demand of timber was intensifying. The short supply of timber and major forestry products was one of the main restricting factors for the development of national economy. Guided by trade policy of government, the export and import trade achieved rapid development.

The imported varieties of forestry products mainly included the following six categories: log, plywood, pulp (including waste paper), paper and paperboard, saw timber and veneer (Tab. 3). Recently, more and more countries has began to restrict the export of log, which has caused the price of log (including temperate zone coniferous timber and tropical broad leaved timber) to increase rapidly and continuously. Thus, the volume of imported log of China has dropped in the middle of the 1990's. Because the government of China executed the policy to prohibit cutting natural forests, the timber supply from natural forests dropped sharply. This resulted in a rapid increase in the import of log, plywood, paper, paperboard and veneer. Moreover, the import of pulp,

TABLE 2

The supply structure of home commercial timber (including outside-state plan logging) (Unit: ten thousand cubic meters).
Struttura di sostegno del commercio interno di legno (unità: diecimila metri cubici).

Diameter class structure	1985	1990	1995	1997
Top grade log	933	841	1044	987
Large log	1536	1385	1719	1625
Medium log	2444	2203	2735	2585
Undersized log	2904	2617	3250	3071
Off-grade log	460	415	515	487
Sum	8277	7460	9264	8754

TABLE 3

Imported situation of products based on wood in China (Ten thousand cubic meters).
Importazione dei prodotti di legno in Cina (unità: diecimila metri cubici).

	1985	1990	1995	1997
Log	983.9	419.4	258.3	446.2
Panel	91.8	1549	234.0	197.7
Others	40.6	48.5	196.0	267.7
Total	1116.3	622.7	688.2	911.6

waste paper and saw timber, kept a steady increasing trend. It was expected that the gross value of imported forestry products of China would for the first time exceed 10 billion dollars in 2000 (Tab. 4).
Among imported log, the proportion of coniferous timber went down from 88.1% in 1985 to 21.4% in 1994 (Tab. 3), whereas, in the same period, the volume of imported broad-leaved timber increased from 11.9% to 78.6% (Tab. 4). The coniferous timber of China was imported mainly from United State, and was composed especially by Douglas fir (*Pseudotsuga menziesii*) and Chinese Hemlock (*Tsuga chinensis*). However, the price of imported timber from United State was higher than that of coniferous timber imported from Russia, New Zealand, that has consequently, increased gradually in recent year.

THE DEVELOPMENT TENDENCY OF CHINESE TIMBER MARKET

The Asian financial crisis had no direct impact on the development of Chinese economy. At that period, in 1998, the Chinese government to protect natural forests resources formulated the policy of prohibition and quota logging natural forests. This entered into force officially in 1999 and caused restricting effects on supply and demand of domestic timber market (ZHANG, 1999). However, thanks to the rebound of economic development of China from the depression, to the increase of domestic consumption and of the imports-exports, an optimistic prediction can be given that in the future, the development tendency of Chinese timber market would still be active. Moreover, this active development tendency would occur mainly because the Chinese government will continue to strengthen the infrastructure construction, increase the exports, enlarge domestic consumption and carry out positive financial policy. In addition, China will implement the policy for encouraging the exports of timber after prohibiting logging natural forests, and execute duty free policy on importing log and saw wood (GUO, 1999).
As for demand, the increase of focal projects, and of infrastructure construction investment, the steady development of industry, agriculture, and the increase of investment in traffic facilities, water conservation, etc., will drive the consumption demand of timber and products based on wood directly or indirectly. Especially after China accessed WTO, introduction of overseas capital and economic preferential policy on developing middle and west of China would fuel the rebound of demand for timber (Tab. 5). According to expert analyses and predictions, the national gross demand for timber would account for 0.11 billion cubic meters in 2000, while the available domestic supply only 65 million cubic meters, the gap is over 40 million.
As regards resources, the domestic supply of timber was about 51 million cubic meters in 1999. The output of timber from natural forest will be reduced of about 10 million cubic meter in three years, according to the natural forests conservation policy executed by the Chinese government. Moreover, the output of commercial timber will be of about 47 million cubic meter in next years (Tab. 2). However, in the fourth quarter of 1999, some part of the domestic timber market, such as that in Fujian and in Guangxi province, was deficient and that caused its price to rise. Predictions are that this situation will be more severe.
As for imported timber, it was estimated that China annually imported 7 million cubic meter timber,

TABLE 4
The gross and structure of log imported by China (Ten thousand cubic meters).
Natura del legno importato in Cina (unità: diecimila metri cubici).

	1985	1990	1995	1997
Coniferous timber	866.7	347.4	61.7	95.5
Non-coniferous timber	117.2	72.1	196.6	350.7
Total	983.9	419.4	258.3	446.2

TABLE 5
The gross and structure of imported paper-based products (Ten thousand cubic meters)
Tipo di prodotti a base di carta importati in Cina (unità: diecimila metri cubici).

	1985	1990	1995	1997
Paper and paper board	87.65	95.18	357.48	619.57
Pulp	54.73	34.18	80.38	152.90
Waste pulp	14.86	42.32	90.62	161.98
Total	157.24	171.68	528.48	934.45

with a maximum of 10 million cubic meters in 1999. Uncontrolled timber importing resulted in waste of resources and loss of state profit. The concerned department of China had taken comprehensive regulating measures to prevent the same variety of timber from being imported, and to control the gross of timber imported from different countries, so as to keep the relative balance and stabilization of international and domestic timber market.

As regards regional markets, after the policy for protecting natural forests was executed, the output of timber in North-east of China was heavily reduced. However, because the impact by the imports of timber from North America and the lack of direct contact between producing and marketing, there appeared the problems of overstocking and sluggish sales of the traditional products of Korean pine (*Pinus koraiensis*), Lacebark pine (*Pinus bungeana*). In Northwest forest area, owing to the national afforestation and greening program for the upper reaches of the Changjian and Yellow Rivers, the stock of timber was sold slowly. It was predicted that with the drive of economic development and policy of west campaign in China, the demand for timber in this region could rebound in the near future. Because of the timber shortage, the price of that represented a steady and rising tendency. Due to rapid economic development, many large-scale infrastructure projects, and increase of investments, the timber consumption would rise quickly. As for the market in the Middle and Lower reaches of Yangtze river, and in the North to Yellow river, the development of timber market was steady, mainly because the social demands in these regions were still not comprehensively driven, except for a special variety of large-sized log of larch which sold well.

Generally speaking, with the development of socialist market oriented economy and sustainable increase of national economy, there will appear the tendency of internationalization, regulation and diversity in Chinese timber market whose foreground looks good.

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ZHANG S. W. 1999 - *Natural forest protection program and timber market in China*. For. China, *1*: 158-163.

RIASSUNTO - La protezione delle limitate risorse forestali naturali cinesi, conseguita per mezzo della politica di divieto del taglio delle foreste naturali realizzata dal governo cinese tra il 1998 ed il 1999, è risultata essenziale. L'analisi della situazione corrente e delle tendenze del mercato del legno in Cina mostra che con il rapido e continuo sviluppo economico, con l'entrata nel WTO e con l'ulteriore apertura del mercato del legno, è in atto uno sviluppo tendenziale della struttura di mercato volto alla diversità dell'offerta ed ai nuovi prodotti. Il forte sviluppo dell'offerta e della domanda di questi nuovi prodotti potrebbe costituire una condizione favorevole alla conservazione delle foreste naturali e dell'ambiente in Cina.

AUTHORS

Deng Gu Cai, Zhi Yong Li, Chinese Academy of Forestry, Beijing 100091, PR China

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Bringing global and national policies to the forest: a case study of sustainable forest management systems in Tasmania

H.J. ELLIOTT and E.R. ROLLEY

ABSTRACT - Forest management in Tasmania follows the principles for forest conservation and utilisation outlined in the Australian National Forest Policy Statement, the 20-year Regional Forestry Agreement between the Tasmanian and Federal governments, and the Montreal Process sustainability criteria and indicators. Conservation of biodiversity, old growth forests, wilderness and other natural and cultural values is achieved through a comprehensive, adequate and representative reserve system based on nationally agreed reserve criteria, legislation to protect threatened species, off-reserve management practices and a legislated Code of Forest Practice. The total reserve system (forest and non-forest) represents 40% of Tasmania's forest and land area. State forests available for harvesting are managed using a multiple-use approach in which areas are zoned for production, protection, recreation and a range of other special values. At the landscape level, planning for biodiversity conservation within the production zone includes maintenance of habitat connectivity and measures to protect critical habitats or key populations of rare and threatened species. All harvested areas on State forest are required by legislation to be regenerated to new forests by sowing or planting. The sustainability of State forest management is assessed using a set of key criteria and indicators contained within an overall Environmental Management System recently accredited under ISO 14001.

Key words: case study, sustainable forest management, Tasmania

INTRODUCTION

Over the last decade there has been a concerted international effort to develop policies and processes for sustainable forest management. Australia has had an active involvement in key international forums on sustainability and, within Australia, the Federal and State governments have led initiatives to put forest management on a sustainable basis. Much of the effort at national and international level has, through the Montreal Process, been directed at developing criteria and indicators for assessing sustainability. The use of indicators and their continued refinement are key factors in measuring the success of the underlying forest management principles and practices which, in Tasmania include:

- Landscape level concepts/approaches to land management
- Development of certification standard (ISO 14000 series) Environmental Management Systems by large forest management organisations.
- Specific land use decision support tools for multiple-use management
- A Forest Practices Code (FOREST PRACTICES BOARD, 2000) for protection of environmental values during harvesting operations
- Continuous improvement in management through a focussed program of R&D

This paper outlines the major systems being used by Forestry Tasmania to address sustainable forest management, and how the sustainability principles developed at national and international levels, particularly the criteria and indicators developed in the Montreal Process, are being refined and brought to the forest in a practical, cost effective manner.

RECENT FOREST POLICY DEVELOPMENT IN AUSTRALIA

In June 1992, at the United Nations Conference on the Environment and Development, Australia endorsed the Global Statement of Principles on Forests and signed a number of conventions relating to Biological Diversity and Climate Change. In December 1992, the National Forest Policy Statement (NFPS, 1992) was published, a document jointly developed by the Federal government of Australia and the State and Territory governments. This Policy Statement set out national goals for the forests of Australia covering: conservation, wood production and industry development, integrated

and co-ordinated decision-making and management, private native forests, plantations, water supply and catchment management, tourism and other economic and social opportunities, employment and training, public awareness, research and development, and international responsibilities.
A process to conduct Comprehensive Regional Assessments in the Australian States was included in the Statement and, after considerable data collection, analysis and negotiation, a Regional Forest Agreement was signed between the State of Tasmania and the Federal government in 1997. This Regional Forest Agreement has an initial term of 20 years with five yearly reviews and its key elements include:

- A comprehensive, adequate and representative (CAR) reserve system based on nationally agreed reserve criteria
- A 17% increase in existing reserves bringing total reservation to 40% of Tasmania's land area
- A conservation program for privately-owned forests
- Implementation of a Threatened Species Protection Strategy
- Development of an Environmental Management System for State forest which meets ISO 14000 series certification standard
- An intensive forest management program involving increased plantation development, and thinning of native forests
- Development of indicators of sustainable forest management

The long term of the Agreement between State and Federal governments, significantly increased conservation measures and the implementation of sustainable forest management practices have provided a stable environment for increased investment by forest industries. This investment is centred on developing a greatly expanded, world scale resource of pine and eucalypt plantations and intensively managed young regrowth eucalypt forests primarily for production of veneers, solid wood products and engineered boards.

TASMANIA'S FORESTS

The total land area of Tasmania is 6.85 million hectares and 3.3 million hectares (48%) is covered by forest. Forestry Tasmania manages some 1.5 million hectares as State forests or Forest Reserves. Privately-owned forests, managed by large forestry companies or small landholders, cover a further 1 million hectares and the remaining forested area is primarily within State-managed conservation reserves. In total, some 40% of Tasmania's forests are in formal and informal reserves.
Tasmania is located below 40 South and has a cool temperate climate. The western and central areas of the State are mountainous and there is a strong rainfall gradient from west to east with some western areas having an annual rainfall of more than 2 500 mm while in some eastern coastal regions annual rainfall is around 500 mm. In common with much of the Australian mainland, Tasmania's forests are dominated by the genus *Eucalyptus* with 29 species covering 2.5 million hectares or 76% of the forested area. These eucalypt forests vary from tall (up to 90 m) wet forests containing highly productive species such as *E. regnans*, *E. obliqua*, *E. delegatensis* and *E. viminalis* to sparse dry eucalypt woodlands in the lower rainfall areas. Cool temperate rainforest occurs over some 0.6 million hectares in the wetter areas of the State (mainly in the western region) and is mostly dominated by myrtle beech, *Nothofagus cunninghamii*, but often contains a variety of native conifers of high conservation value including Huon pine (*Lagarostrobos franklinii*), King Billy pine (*Athrotaxis selaginoides*) and celery-top pine (*Phyllocladus aspleniifolius*). In addition to these areas of natural forest there are approximately 0.2 million hectares of plantations of *Pinus radiata* and *Eucalyptus* (mainly *E. globulus* and *E. nitens*).

FORESTRY TASMANIA'S APPROACH TO LAND MANAGEMENT

Forestry Tasmania has developed a concept of forestry in the landscape which guides the detailed forest management practices down to the harvesting unit level. At the landscape level the approach is to use a gradient of increasing intensity of forest management from areas adjacent to World Heritage Areas and other reserves through to areas adjacent to intensive land management such as agriculture and urban development (ROLLEY, 1998). The major forms of forest management in Tasmania are long rotation (150-200 years) special species management, extensive native eucalypt forestry (80-90 year rotation), more intensive management of native eucalypt forests to obtain sawlogs at an earlier age through various thinning regimes, and intensive short rotation (15-25 years) plantation forestry using fast growing eucalypt species and *Pinus radiata*. Where possible, the long rotation forestry is practised in the least disturbed areas and the plantation forestry is practised in areas on or adjacent to farmland and other developed land.
Forestry Tasmania has a multiple-use approach to managing the large range of values contained within State forest. In order to optimise management and balance the competing demands on the forest estate, a Management Decision Classification (MDC) system is used to zone land which is available for multiple use management. This system records decisions on appropriate land use made by managers based on the best available information (ORR, GERRAND, 1998). The system operates in a context of Federal and State legislation which regulates many aspects of forest management such as protection of endangered species, parks and wildlife management and forest practices.
The MDC identifies two levels of zoning: Primary Zones and Special Management Zones. The Primary Zones are *Protection* - land that has been set aside from wood production to protect special values;

Conditional – land for which no long term-decision on future use has been made and which will be allocated to one of the other Primary Zones once research and evaluation have been conducted; and *Production* – land available for wood production. The Special Management Zones identify areas where special emphasis beyond that given by the Primary Zones is placed on management for particular values. There are currently eighteen categories of Special Management Zones including *Fauna*, *Flora*, *Cultural Heritage*, *Landscape*, *Apiary*, *Recreation*, *Water Supply*, *Long Rotation Wood Production*, *Plantation* and *Research*.

The MDC sets out broad forest management objectives for particular areas of land. At the harvesting unit level, the *Forest Practices Act* sets operational standards and guidelines for best practice and provides for a Forest Practice Code which is the main tool used by forest managers for implementing practical protection measures for soil, water, plants and animals on both State and private land. Forest Practices Plans must be drawn up before commercial forest harvesting operations are allowed to proceed, and these plans contain specific prescriptions covering all aspects of the operation which could impact on environmental values. The Forest Practices Code is administered by an independent authority, The Forest Practices Board, and qualified and accredited Forest Practices Officers are charged with assessing and approving Forest Practices Plans on behalf of this Board.

Local government bodies, communities and individuals can also have important inputs into the planning and operational stages of forest management. These inputs are sought and given when planning forest operations, particularly where there may be concern about impacts of forestry on other existing or planned land use. This consultation process can result, for example, in revised methods of harvesting or changed harvesting unit areas and boundaries.

Developing practical and cost effective sustainability indicators

The principle of sustainable managing all types of forests in order to meet the needs of present and future generations was recognised by the 1992 UN Conference on Environment and Development. To facilitate the assessment of sustainable forest management, much international effort has gone into developing a set of criteria and indicators. Australia was a member of the Working Group on Criteria and Indicators for the Conservation and Sustainable Management of Temperate and Boreal Forests, also known as the Montreal Process Working Group formed in 1994 following the UN Conference and the Seminar on Sustainable Development of Boreal and Temperate Forests held in Canada in 1993. The twelve countries comprising the Montreal Process Working Group represent some 60% of the World's forests and over 90% of the World's temperate and Boreal Forests. This Group developed a comprehensive framework of seven criteria and 67 indicators of sustainable forest management which were endorsed through the Santiago Declaration in Chile in 1995.

Using these internationally agreed broad criteria and indicators as a model, Australia has developed an Australian framework of regional level indicators of sustainable forest management (MIG, 1998). This framework contains some of the original national-level indicators, some other national indicators reworded to suit regional application, and some new and/or interim indicators. In addition, the indicators have been divided into three categories: those which can be reported against immediately for many areas of forests, those which can be measured for some areas of forest but where there remain methodological or resourcing issues; and those for which significant research and development is required to assess if there is a practical, sensitive and cost-effective means of implementation. This framework is being used at the regional level and in the Regional Forest Agreement (RFA) process between the Australian States and the Commonwealth referred to earlier in this paper.

Following the signing of the Regional Forest Agreement, Tasmania has used the Regional Framework to develop a core set of indicators for use in its forests. The challenge is to convert what can appear to be somewhat remote and general principles into tools which can actually be used at the harvesting unit level in practical forest management. This core set differs in some areas from the Regional Framework because of specific Tasmanian conditions, availability of appropriate data sets and ability to integrate indicators into existing processes in a meaningful and cost effective manner. Even in a small State such as Tasmania which has had intensive forest management procedures in place for some 80 years, is well mapped and has sophisticated inventory systems, the data for some indicators proposed in the Regional Framework were not available for implementation in the short term. Therefore, a revised core set of indicators derived from these international, national and regional processes has been developed and incorporated by Forestry Tasmania into an overall Environmental Management System (recently accredited under ISO 14001) and includes the following:

- Extent of forest types on State forest
- Extent of forest by growth-stage on State forest
- Numbers of threatened forest dwelling species by status
- Forest land available for timber production
- Annual quantity of wood products harvested
- Extent of plantation forests
- Area of forest affected by agents which may change ecosystem health and vitality
- Compliance with provisions of the Forest Practice Code
- Use of chemicals on State forest
- Change in forest carbon stocks
- Value of wood and wood products production

- Visits to recreational areas
- Value of forest estate
- Level of expenditure on R&D
- Safety performance
- Legal, institutional and economic framework for forest conservation

In addition to these current indicators of sustainable management, several others such as "proportion of harvesting unit in snig tracks and landings" are being researched for suitable measurement techniques and will be added to the set when cost effective and sensitive measures are available.

MECHANISMS FOR CONTINUOUS IMPROVEMENT

Maintenance of sustainable forest management practices requires continuing research and development across the wide range of forest values, both wood and non-wood. In addition to the more traditional research support provided within large forest management companies and agencies, a long term ecological research program has been established in Tasmania to provide an experimental research base to underpin future forest management practices for conservation and sustainable wood production

The Warra Long Term Ecological Research (LTER) site (WARRA POLICY COMMITTEE, 1999) is situated in the southern forests of Tasmania. It is a sister site to dozens of LTER sites across the world and has been established to facilitate the understanding of ecological processes in wet (*Eucalyptus obliqua*) forests, Tasmania's main forest type. These forests are part of the southern cool temperate wet forest biome. The programs foster multi-disciplinary research within a long-term framework. The site contains both working forests and conservation reserves and appropriate management prescriptions and practices prevail in different parts of the site.

The main aims of the Warra LTER program are as follows:

- To understand fundamental ecological processes in *E. obliqua* wet forests.
- To assess and monitor biodiversity and geodiversity.
- To determine the long term effects of different forest management regimes on natural diversity and ecological processes and thus assess their sustainability.
- Where necessary, to develop alternative management regimes.
- To provide an integrated multi-disciplinary focus which complements research programs elsewhere in Tasmania.
- To link Tasmanian forest research with national and international programs having a long term ecological focus.

Currently, several different silvicultural methods for harvesting and regenerating wet eucalypt forest are being tested at the Warra site. Numerous biodiversity, soils and water studies are in place within these trials and/or at other parts of the site to examine both the natural systems and the effects of the silvicultural treatments. The results of these studies will be used as a basis for changes to forest management regimes in this forest type if these are required.

DISCUSSION

Sustainable forest management requires appropriate policy frameworks, land use concepts and sensitive reserve and off-reserve management. Within areas available for forest harvesting, some form of land-use decision support system is needed which takes into account the range of forest values present in the area. During harvesting, operations must conform to a comprehensive and monitored Code of Forest Practice containing protection measures for environmental values.

In addition to these policies and regulations/guidelines, the use of sustainability indicators covering the key criteria of biodiversity, productivity, forest health, soil and water, carbon stocks and socio-economic values provides targets for performance and enables managers to focus on areas needing improvement.

In Tasmania, a stable policy framework for sustainable forest management exists through the Regional Forest Agreement between the Federal and State governments, and appropriate land management systems have been developed to cover the range of forest types present. A basic set of sustainability indicators developed through the Montreal Process and Federal and State analysis is in place within Forestry Tasmania's Environmental Management System. These indicators are beginning to be tested at the operational level in State-managed forests and we envisage a dynamic process where existing indicators are altered and new ones developed as more research results become available from the Warra LTER site and other trials. The continued use of cost effective indicators matched to local conditions and practices will be an integral part of the overall system for providing sustainable forest management.

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RIASSUNTO – La gestione forestale in Tasmania segue i principi per la conservazione ed uso delle foreste delineati nell'*Australian National Forest Policy Statement*, nell'accor-

do *20-year Regional Forestry Agreement* tra il governo della Tasmania e quello Federale, e nei criteri ed indicatori di sostenibilità definiti nella Conferenza di Montreal. La tutela della biodiversità, della crescita delle "vecchie" foreste, della flora e della fauna selvatica e di altri valori naturali e culturali si realizza attraverso un complesso sistema di riserve completo e rappresentativo, basato su criteri sottoscritti a livello nazionale, sulla legislazione per la tutela delle specie a rischio e su di una legge che definisce il *Code of Forest Practice*. Il sistema di riserve (forestale e non) in Tasmania costituisce in totale il 40% del territorio forestale ed agrario. Le foreste statali destinate ai tagli sono gestite secondo un approccio multi-uso, in cui le aree interessate sono suddivise in zone per la produzione, per la protezione, per la fruizione ricreazionale e per una serie di altri impieghi speciali. A livello di paesaggio, la pianificazione della tutela della biodiversità all'interno delle zone di produzione include la conservazione delle connessioni ecologiche degli habitat, le misure per la protezione di habitat critici o di popolazioni chiave di specie rare e di specie a rischio. Tutte le aree di taglio delle foreste statali devono essere riforestate per legge. La sostenibilità della gestione delle foreste statali viene valutata attraverso una serie di criteri ed indicatori chiave definiti all'interno di un sistema complessivo di gestione ambientale (Environmental Management System) recentemente accreditato dall' ISO 14001.

AUTHORS

Humphrey J. Elliott, Evan R. Rolley, Forestry Tasmania, GPO Box 207, Hobart 7000, Tasmania, Australia. Ph: 61 3 6223 2194, Fax: 61 3 6233 8292, Email: helliott@ozemail.com.au*

**Corresponding author*

The effects of economic factors on the demand for natural recreational forests in Korea

J.S. KIM

ABSTRACT - Demand for tourism and recreation in Korea has increased remarkably. In Korea, forest resources have played an important role in the provision of various outdoor recreation opportunities to meet recreational needs of the society. We found that the demand for recreational forests depends not only on the number of recreational forests, but also on economic factors. We claim that the dependence of the demand for recreational forests on the income level is stronger than the dependence on the number of recreational forests. To achieve the intended objectives of establishing recreational forests, we need to incorporate the expectations of both demand and supply sides.

Key words: community approach, demand, market failure, recreational forest

INTRODUCTION

Efficient usage and conservation of forests have been a new paradigm of sustainable development and multi-purpose use of forests in most countries. And forests have many different functions including not only the economic function of timber and nom-timber production, but also the public functions like land conservation, improvement of water resources, wildlife protection, protection of nature, recreations and others.

Due to the large amounts of all types of pollution resulting from rapid industrialization and urbanization in Korea, there has been a fast increase in demand for public functions of forests. Among various public functions of forests, importance of recreational function has been considered seriously even though it is fairly new to us. And it is expected that the trend will continue in the future. In fact, as the society is getting complex and diverse, recreational activities become major components of everyday living and the degree of its importance gets larger. In addition, the people's demand for recreational activities increases very fast fueled by rising available income. After all, we can expect that people will spend more time and money for recreational activities as social and economic conditions improve.

Forest policy in Korea has changed very fast as we realize benefits of utilizing forests as public goods. Importance of this kind of interest will be determined by the demands from people who are recipients of those benefits. Therefore, policy for the usage and management of forests as public goods should be able to meet people's needs and demands. It has been pointed out that there is possible market failure for some types of forest recreation (KIM, 1988). So government or public offices must provide forest recreation services or give some incentives for the private sector to provide them. In this respect, the Ministry of Agriculture and Forest (MAF) of Korea adopted a project of building up recreational forests to utilize forests as good recreational and nature educational sites and source of income for forest owners in 1988. But supplying more recreational forests is not enough. To achieve more efficient management of recreational forests, it is necessary to see how the demand for recreational forests has been changed and affected by economic and social factors.

CHANGES OF SOCIAL AND ECONOMIC CONDITION IN KOREA

Because of rapid industrialization and urbanization, recreation and leisure demand has increased along with people's income level and free time (SPINK, 1994). The gross national product (GNP) per capita has increased by more than 4,500% from 1970 to 1996. GNP and per capita GNP reached their peaks at 518.3 billion dollars and 11,380 dollars respectively in 1996. However, due to so-called IMF crisis which happened in the end of 1997 the Korean economy went down sharply in 1998 and is now slowly recovering. Korean employees' working hours per week have decreased, with an exception of 1999 (during that year it increased slightly due to possible effects after IMF turmoil). The number of passenger cars and the total distance of road have increased a lot and it made easy for people to travel. Meanwhile, the composition of consumption expenditure has changed as people's lifestyle changed. Expenditure for basic living items such as food, clothing, and housing have decreased or remained stable, but expenditures for items like communication, transportation, medical and recreation are increasing. Especially, the proportion of expenditure for recreation and cultural activities has increased from 2.4% of final consumption expenditure in 1970 to 8.48% in 1999.

Traditionally, recreation was perceived as special activities for those who hold high social and economic status in Korea. During the period of rapid economic development in 1960's and 70's, most people perceived recreational activities as non productive and hard working ethics prevailed. So people simply spent minimum time for recreational activities. But the situation gradually changed as the economy grew fast in late 70's and eventually people gave some value for leisure activities. Especially, labor liberation movement not only raised workers' income, but also gave opportunities of judging their lives rather critically. This change naturally induced people to seek more leisure hours and spent more time and money toward recreational activities (SPINK, 1994).

However, since these kinds of change tend not to care about others, rapid increase in the demand for recreational activities with no appropriate recreational culture deteriorated the condition of natural resources, especially of forest resources. A lot of waste was thrown everywhere and illegal cooking and camping in forest areas was common. We need to build up more efficient management plan to preserve our natural resources along with good educational program to teach environmental problems. In this respect, developing a long-term plan to establish better recreational culture is urgently needed since it may not be achieved in short time period.

USE OF FOREST RESOURCES FOR RECREATIONAL PURPOSES

In Korea, as of 1998, forestry land is about 6.5 million ha representing 65% of the total land area. Despite large proportion of forestry land, the forestry land per capita is very low at less than 0.2 ha due to large population. Meanwhile, national and public forests comprise 22% and 7.6% of the total forestry land respectively and the remaining 70.4% is private forests.

Even though the area of national forest is increasing, most of the forestry lands in Korea are privately owned. At the same time, the number of owners and lots it continuously increasing, which means the area per owner and lot is decreasing. This causes many difficulties in managing forestry land efficiently and establishing a good forest management policy.

Since we established the first Chirisan National Park with the same concept as national parks in the United States in 1967, twenty national parks have been named. Total area of national parks is 6,473 km^2 including 2,648 km^2 of sea area. Thus, land park area is only 3,825 km^2 that comprise about 3.9% of total land area of Korea. Those national parks, including three sea parks, are managed by the National Parks Authority mainly with its internal revenue. Government subsidy is just 15% of total costs. Those parks are mostly small in size, but with oriental scenic beauty. The main objectives behind the establishment of national parks are to preserve environment and natural beauty, and promote sustainable forest management. It is believed that this eventually contributes to the enhancement of public health, leisure and recreational activities.

In 1988, the natural recreational forest project was introduced as part of major forestry initiative to implement multiple use management of forests. And it is linked with increasing farmers' income and meeting the rapid increase in demand for forest recreations. As of 1988, 166 natural recreation forest zones were designated. Average area per recreational forest site is 1,987 ha for national forests and it is only 310 ha and 147 ha for public and private forests respectively.

The basic guidelines for developing recreational forests give priority to national and public forests in areas with convenient transportation and beautiful scenery. Private forest owners are encouraged to develop their forests for income projects and part of the development expenses is supported by the government. Unlike parks and general resort areas, the natural recreational forests have the characteristics of preserving natural scenery while limiting damage to nature with basic recreation facilities such as trails, green showers, benches, picnic tables, camp grounds, sports facilities, shelters and nature observation places.

LOCATION AND THE NUMBER OF VISITORS TO NATIONAL PARKS AND RECREATIONAL FORESTS

Most national parks and recreational forest in Korea are located in the southern part of country. Big cities and Kyonggi province are most densely populated areas and these areas have less number of national parks and recreational forests than other areas.

Numbers of visitors to the national parks and recreational forests have increased except in 1997 and 1998 when IMF crisis hit Korean economy. However, among twenty national parks, only four land parks (Soraksan, Pukansan, Chirisan, Songnisan) and two sea parks (Hallyohaesang and Pyonsanbando) have attracted more than one million visitors in 1999. Number of visitors to different national parks differs and it seems that people go to popular ones no matter how far they are located from their places of residence. The number of visitors to the recreational forests has increased faster than to the national parks. However, average number of visitors to recreational forests has not increased recently. This may imply that the increasing trend of visitors to recreational forests mainly gave rise to more recreational forests.

ESTIMATION RESULTS OF THE DEMAND FOR RECREATIONAL FORESTS

The number of visitors to recreational forests may depend on various factors like entrance fee, cost of going to the place, available income level, leisure hours, accessibility to the place and others

We analyzed the demand for recreational forest by using multiple linear regression method. Several economic and social factors were used to explain the demand for recreational forest. Since entrance fee has been very small and has not changed much, other factors were taken into consideration. We, however, found that per capita GNP and total length of road are the only variables that are significant. Other variables we considered including number of passenger cars, working hours, etc.

We used time-series aggregate date for 1987-1999, and two different estimation equations: Model I included three explanatory variables - number of places, GNP per capita, and length of road; whereas Model II removed the number of places from explanatory variables.

ESTIMATION RESULTS

We hypothesized that an increase in people's available income induces more visits to recreational forests. Different from the previous estimation (FOREST ADMINISTRATION, 1998; FOREST RESEARCH INSTITUTE, 1999), we found that the number of designated recreational forests has no significant effects on the demand for recreational forests. The estimation results are summarized in Tab. 1.

To compare this result with the demand for national parks, we used the same explanatory variables in our estimation equation and found that the effect of income factor is greater for national parks than for recreational forests. An increase of per capita GNP by 10,000 won (equivalent to about $ 8.70) will generate the entrance to recreational forests and national parks by 3,741 persons and 50,074 persons respectively. So we can conclude that people prefer national parks to recreational forest. One possible reason for this is national parks have better scenic view and are larger in size. At the same time people have more information about national parks since they were established earlier. Even though most recreational forests have better facilities, it seems that recreational forests attract only those who are living nearby. The sign of the estimated coefficient of length of road is opposite for each of two cases. So we can conclude that the accessibility is not the main concern for people in terms of deciding whether to go to national parks or not. The possible reason for this is that most national parks are well known by public and rather good public transportation is readily available between most cities and national parks

Meanwhile, we found that people prefer public and private recreational forests to national ones. Even though the differences were not big, the effect of income factor on the demand for national recreation forests was smaller than for public-private ones. The possible reason for this may be that public-private recreational forests have better facilities compared to national ones.

To observe the effect of income factor on the demand for other recreational activities we estimated the equation for number of travelers overseas with explanatory variables of per capita GDP and exchange rate. We found that an increase in income increases overseas travel and the exchange rate also affects overseas travel. The effect of income increase, however, will be the biggest in the case of national parks and the least in the case of overseas travel if other things are considered being equal.

CONCLUSION

Since we found that the demand for recreational forests is affected by income factor, we expect that more recreational forests will be needed as economy grows and people's leisure hours increase. However, we must not assume that we can achieve the intended objective of establishing recreational forests simply by supplying more. As people's income increases and their living standard improves they tend to go to places with better environment and facilities. We also found that the locations of recreational forest are

TABLE 1

*Summary of estimation results. Numbers in parenthesis are t-ratio; * significant at 1%, ** significant at 5%.*
*Sommario dei risultati stimati. I numeri nelle parentesi indicano il t-ratio; * significativi al 1%, ** significativi al 5%.*

Variables	Recreational forests			No. of overseas
	Model I	Model II	National parks	travel
Intercept	-2,780,679 (-3.66)*	-3,779,811 (-15.4)*	1867.20 (0.737)	-529.817 (-7.787)*
Number of places	9,698.33 (1.383)	-	-	-
GNP / Capita	2778.04 (2.873)**	3741.46 (5.246)*	50.0747 (6.998)*	1199.87 (10.202)*
Length of road	28.54 (3.208)**	37.83 (6.094)*	-0.3006 (-3.595)*	-
Exchange rate (won/$)	-	-	-	-106.70 (1.972)**
R^2	0.9927	0.9904	0.8936	0.9577

concentrated in certain area in Korea. It seems necessary to develop them rather evenly in terms of location to provide better services to more people. After all, to meet demands and needs of people we carefully forecast the demand for recreational forests and have to provide appropriate services to attract more people in the future.

Even though here we considered demand side only, it seems very important to incorporate both demand and supply sides. Having more recreational forests is good for demanders, but not to all. In many cases, this kind of development brings more environmental problems to the community such as traffic congestion, more littering, water pollution, increase in noise, more landscape destruction and others. SONG (1998) shows that most residents in the recreational forest area are concerned about environmental effects and see the development negatively. Therefore, central and local government must take into account also local residents' demands. To achieve the intended objectives of recreational forests, we need to calculate all possible benefits and costs resulting from the development of recreational forests. In this respect, we need to understand the importance of co-participation between providers and users of recreational forests before planning to supply more recreational forests. After all, we need to use so-called community approach in developing recreational forests so that they provide not only good recreational services to the society, but also improve local living standards, increase employment opportunity and induce more active investment in the community.

Since we expect larger demand for recreational forests in the future, government needs to set up good management plans along with better rules and regulations. We need to put more attention on environmental and ecological aspects. One example of good rules is an introduction of a no visit day to recreational forests. Every Tuesday, except in July and August, all recreational forests are closed for a rest. One example of bad regulations is that government enacted a new law that allows general restaurants to operate in recreational forests for the sake of convenience. Previously, only snack bars could operate in the recreational forests and this change may not be a good policy for preserving environment and sustaining our natural resources.

After all, since forests have to fulfill various functions in the long-term as we mentioned earlier, it is very important that forests would be managed in a non-destructive and sustainable manner. Therefore, we need to consider not only the economic dimension, but also the biological and physical dimension, and social dimension in developing recreational forests.

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RIASSUNTO – La domanda di turismo e più in generale di attività ricreazionali è aumentata notevolmente in Corea. Le risorse forestali hanno svolto un ruolo importante nella creazione di attività ricreazionali all'aperto in Corea e nel soddisfare le necessità di svago della società. Questo lavoro evidenzia che la domanda di foreste concepite per una fruizione ricreazionale dipende non solo dalla loro disponibilità, ma soprattutto da fattori economici come il livello dei redditi. Per raggiungere gli obiettivi di creare delle foreste concepite per una fruizione ricreazionale, bisogna tener conto delle aspettative sia sul fronte della domanda che su quello dell'offerta.

AUTHOR

Jin-Sung Kim, Department of Food and Resource Economics, Korea University, Anam-dong, Sungbuk-ku, Seoul, 136-701, Korea

A case study on ecological environmental protection model in Three-Gorges Reservoir Area, China

Z.Y. LI

ABSTRACT - The ecological and environmental security of the Three-Gorges Reservoir Area has been seriously affected by soil erosion and sand deposit in reservoir. To control the ecological and environmental damages, farmers have taken special actions that include mountain forest recovery, afforestation of agricultural land, etc. The results show that the practice of Huanghua's farmer is effective and successful to control soil erosion, to prevent the damage of floodwater and drought, to improve the situation of rural ecology and environment. Experts point out that the Huanghua's model is suitable to be applied in other regions.

Key words: ecology, environment, forestry, sustainable development

INTRODUCTION

In 1998, the unusually serious flood disaster throughout the watershed area of Yangtze River brought great loss in economy development, especially in the well developed in society and economy downstream areas. Adding losses caused by flood disaster in other watersheds, the direct economic loss in the whole country was more than 320 billion RMB (STATE FORESTRY ADMINISTRATION, 1999a).

As regards Three-Gorge Reservoir, where water losses and soil erosion have been serious in history, and that face crisis of river mud-sand sedimentation today, forests conservation and vegetation rehabilitation, in mainstreams and side streams throughout Yangtze River watershed, is of paramount importance. That is mainly due to the fact that there is a great farming population and a heavy pressure from food suppliers, which has brought out the contradiction between forestry and agriculture, and is getting more and more serious with increasing population (YANG, 1994). It is testified by domestic and overseas research, that reclaiming steep slope in the watershed is main cause of water and soil losses and river mud-sand sedimentation. In view of this problem, State Council issued the "*Urgent Circular on Protecting Forest Resources and Clamping Down Destruction of Forest for Land Reclamation*" in 1998, which required converting the cultivated land more than 25 gradient for forestry, in the hope of controlling day by day serious soil erosion in most main watersheds in China, to improve environment, and advance the environment capability and bearing capacity of the watershed areas to flood disaster (STATE FORESTRY ADMINISTRATION, 1999b).

To insure that the fateful decision was executed smoothly, effectively and would work in long term, in early November 1998, the expert group of Chinese Academy of Forestry investigated the status, problems and trends of agricultural comprehensive development, protection, rehabilitation and reconstruction of forest vegetation in the range of Three-Gorge Reservoir. Huanghua township in Yichang County, Hubei Province, located in Three-Gorge Dam area, was asked to develop watershed management with the principles of "resettling residents living in the reservoir area and make them withdraw farming, enclosure of hillside for forest cultivation, and ecological emigration", and received notable effects. To carry out the Urgent Circular of State Council, in October, 1998, Forestry Department of Hubei Province and Forestry Bureau of Yichang City, worked together to implement the pilot project of "closing hillsides for cultivating forest, and moving out of agriculture land for planting tree" in whole township. The results of the investigation indicated that the practice and programming of "moving out of agriculture land for planting tree" in Huanghua township had clear orientation and effective strategies, was somehow representative, and reflected positive ecological economic direction of afforestation of land moving out of agriculture in watershed areas.

This could represent a model for reference to implement, in an all-round way, environment construction and sustainable development in rural area in China.

Socio-economic conditions

Huanghua village lies in the middle of Yichang county, Hubei Province, with total area of 11,814 ha, among which, forestry land is 9,210 ha, arable land 886 ha, and others 1,718 ha. The topography there is complex with altitude range from 132 to 1,062 meters; Low Mountain and hills are the main physiognomy type. Plenty rainfall, abundant sunshine, temperate climate, clearly demarcated four seasons with cold winter and hot summer are the main climatic features in Huanghua township. Annual rainfall is about 1,100-1,600 mm, of which half in summer. And annual mean temperature is 16.9 °C. Frost-free season is 234 days.

Huanghua Township is composed of 10 administrative villages, 89 sub-villagers, and 3,821 households with the population of 14,254 of which 5,623-labor force. It ranks fifth in integrated economic power among 20 townships in Yichang County. The gross output of industry and agriculture was 247 million RMB. Major crops, economic forest tree species grown and planted ther include rice, wheat, maize, sweet potato, potato, citrus, chestnut and alpine vegetation. Food output in the whole township, totaled 7,818 tons in 1997, was more than self-sufficient, oilseed 700 tons, economic crops (vegetables) 4,844 tons and fruits 1,100 tons. Per capita net income was 2,858 RMB.

Forestry development status

Forestry land of 9,210 ha occupied 78% of the area of whole township, among which forested land covers 5,971 ha, scattered woodland 1,725 ha, shrub land 1,404 ha, unestablished forest land 75 ha, and land liable to forest 35 ha. Forest stock reached 195,604 m^3. Average of stand stock was 0.17 $m^3 ha^{-1}$. Because of long-term irrational management and lack of investment, the quality of stand composed of single tree species was not good. Masson's pine (*Pinus massoniana*), pure man-made forest, was the main stand type, under which vegetation was sparse, and resulted in low ecological protection function. Masson's pine (*Pinus massoniana*) was the main arbor species. 90% of not-closed forest and shrub woodland was destroyed by villagers collecting fuelwood, which reduced its ecological protection effectiveness. Most of Huanghua Township lies in Huangbo river efflorescence shale area, where soil erosion was the most serious in Southern China, due to serious destruction of forest. It obtained obvious effect through comprehensive management since the carrying out of "The Shelterbelt Program for Yangtze River", but soil erosion was not controlled. Now the area with moderate and upward degree of soil erosion is 5,653 ha, covering 47.9% of the total. And soil erosion modulus is 4,120 ton per square kilometer every year.

Besides that farming land more than 25 gradients should move out of agriculture for afforestation, Huanghua Township decided that dry land lower than 25 gradient, with serious water and soil erosion and very low income from crops, and where household would move out of farming, could be taken as object for moving out of agriculture for afforestation. Statistics showed that farming land more than 25 gradient, with an area of 85 ha covering 48.1% of total area, should moved out of agriculture for afforestation.

Activities for conserving, rehabilitating and rebuilding forest and vegetation

After moving out of farming, villagers' needs in economy development and enduring capacity of local labor force mainly gave way to building both protected forests and economic forests. Whereas timber forests were planted where the site quality was high and there was lack of labor force. Huanghua Township had made the plan and design of 85 ha of protection forest, 91 ha of economic forest, and 35 ha of timber forest.

As to species selection, the best are native species, with developed root system and better capability of water and soil conservation, and of resisting drought and infertile land. At the same time, developing properly timber and economic forest species is necessary: these should have features of fast growing, high economic benefit and good market foreground, and some protection function. According to the above principles, Huanghua township selected 11 species for 11 types of planting design, among which, Masson's pine (*Pinus maassoniana*) and Slash pine forest covered 64 ha, Black locust (*Robinia pseudoaeacia*) 15 ha, Oriental Oak (*Quercus variabilis*) 1 ha, Mourning Cypress (*Cupressus funebris*) 3 ha, Chinese Chestnut (*Castanea mollissima*) 50 ha, Persimmon (*Diospyros kaki*) 1 ha, *Citrus nobillis* 35 ha, peach (*Prunus persica*) 2 ha, Ginkgo Maidenhair tree (*Ginkgo biloba*) 1 ha, Euconmmia (*Eucommia ulmoides*) 1 ha, and *Populus euramericana* 39 ha.

In most of Huanghua Township in efflorescence shale area, water holding and fertile conservation capability of soil was low, so was shrub coverage degree under forest, and water and soil erosion was serious. Closing hillside for forest afforestation with little cost and immediate effect, was an important way to accelerate vegetation rehabilitation, forest resource cultivation and controlling water and soil erosion. The following were taken for doing closure of hillsides for regeneration well by Huanghua Township: Firstly, setting up group leader, who is responsible for closure of hillsides for regeneration in township and village levels. Secondly, recruiting full-time forest guards each of whom is responsible for 133 ha of forest, according to which 31 forest guards would be needed in the whole township. Thirdly, raising funds for forest protection, and according to the economic condition of Huanghua Township, forest guards should be paid 6,000 RMB each year. Finally, setting up and strengthening contract responsibility system of technology combined with economic benefit, assign task of closing hillsides and management to each person with a specific plot, assess forest guards periodically, and then pay them according to the assessment.

Firstly, demarcate area to be closed off reasonably. The region where it is easy to renew vegetation after closing off could be demarcated as area of closure of hillsides for regeneration. In the second place, establish signs of closing off. Thirdly, based on growth and development feature of forest, programmed sub-compartment should be closed off for 5 years at a stretch, to carry out complete closure, half-closure and rotation closure. Lastly, for gaps where the density of tree distribution didn't reach reasonable level, or natural breeding was weak, or seedlings were unequally distributed, areas should be replanted or enriched with seedlings.

At that time, firewood covered less than 40% of energy in the township. In closed off areas, to solve conflict between firewood demand of villagers and closure of hillsides, reasonable measures were to be adopted to reduce consumption of forest resources.

PRACTICE OF ECOLOGICAL IMMIGRATION

Yangjiaban village lies in the middle reaches of Huangbai River, with a land area of 11.8 square kilometer. The village was built on hill slope; 80% of the land is hillsides, whereas the remaining 20% is arable land. The village is composed of 12 sub-villages, with a population of 2,027. Despite such a vast area and few people, the low food output made villagers reclaiming steep slope for cultivation to meet their food needs. However, that caused serious damage to vegetation. Uncontrolled and illegal cuttings were serious because of poverty. Villagers would produce charcoal and sale wood as their main pocketbook. Forest in the mountain went to the fringe of exhaustion. Aimed at this situation, the Committee of Yangjiaban village put forward a policy framework of "moving sub-villages from mountain, withdrawing agriculture for forest cultivation, resettling villagers for closing off, conserving water and soil".

In 1993, the Village repealed the twelfth sub-village, this made 8 ha cultivated land move out of agriculture, where Black locust (*Robinia pseudoacacia*) was planted. Dismantling houses and closing off mountains for regeneration, which gave illegal lumberer no transfer stations and shelter spots, put an end to uncontrolled and illegal cutting and protected forests. At the same time, the Village paid great attention to manage 33 ha psammitic regosol hill formed from weathered shale at the foot of mountain, planting it with Black locust (*Robinia pseudoaeacia*), Oriental Oak (*Quercus variabilis*) and some economic forest, built 110 sand culvert, and planted 17 ha of shrubs and grass. So water and soil erosion was effectively under control, and working and living environment was obviously improved.

Models and experience of Huanghua Township worked out a series of preferential policies, and insisted on the principal of "willing moving, satisfied resettlement, and enriching them". That was to say, the moving down households could be arranged in any sub-village by harmonizing farming land and freeing land occupancy fee for building houses. Laborers were offered jobs in the Village's corporation with the utmost effort, it supported them in engaging in the business, industry and sideline activities, so that now every household have their storied building and live good life.

The pattern of "resettlement and withdrawing from farming, closing hillsides for regeneration of forest, and ecological emigration" in Yangjiaban Village, Huanghua Township, did give results: forest was managed well, the mountain became green, torrential flood didn't erode cultivated land any longer, quicksand didn't bury farmland any more, and enriched villagers.

CONCLUSIONS

Research and investigation on the spot in the regions belonging to Three-Gorge reservoir area indicated that if the phenomena of "damaging forest to reclaim and occupying woodland randomly" could be controlled effectively and be uprooted, and policy of "closing hillsides for forest cultivation and moving out of agriculture for afforestation" could be carried out completely, they were very important for environment protection, rehabilitation of forests, control of soil erosion and accumulation of sediment in the reservoir area, and even to ecological and economic security of Three-Gorge Project. We believed that in Huanghua township, the object of policy of " closing hillside for afforestation, moving out of agriculture for forestry, and ecological resettling residents in the reservoir area" was right, the measures were effective, the ecological and economic effect was obvious, the developing direction was right, and its practice and experience was worthy of extending to other watershed areas for reference when carrying out environment construction in Three-Gorge reservoir area.

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RIASSUNTO – La sicurezza ambientale ed ecologica della *Three-Gorges Reservoir Area* è stata seriamente influenzata dall'erosione del suolo e dai depositi di sabbia accumulatisi all'interno dei bacini idrici. Per contenere i danni ecologici ed ambientali gli agricoltori hanno adottato una serie di misure speciali quali il recupero delle foreste montane, la riforestazione dei terreni agricoli, ecc. I risultati mostrano che le pratiche adottate dagli agricoltori di Huanghua sono risultate efficaci nel controllo dell'erosione del suolo, nel prevenire i danni derivanti dalle alluvioni e dalla siccità ed in generale nel migliorare le locali condizioni ecologiche ed ambientali. Gli esperti sostengono che il modello di tutela ambientale adottato nel Huanghua sia applicabile anche in altre regioni affette da simili problematiche.

AUTHOR

Zhi Yong Li, Research Institute of Forestry Policy and Information, Chinese Academy of Forestry, P.O. Box 76, Beijing 100091, China

Malaysia's quest towards sustainable forest management

T.Y. CHIN

ABSTRACT - Malaysia is fully aware of the need for effective forest management and conservation not only to ensure a sustained supply of wood and non-wood forest produce but also as a need to maintain the services provided by the forest. These include safeguarding the environment, providing sanctuary for wildlife and serving as invaluable storehouse of genetic resources for the improvement of its indigenous tree species, agricultural crops and livestock. This renewable asset will continue to be managed in accordance with national objectives and priorities so that the country will continue to enjoy the benefits generated from them. Malaysia's commitment to sustainable forest management is attested through its current forestry management and forest development practices, allocation of financial resources to carry out these activities, undertaking of bilateral sustainable forest management projects and identifying criteria and operational indicators for the measurement of sustainable forest management. This paper attempts to review some of these approaches, as well as to indicate how far Malaysia has travelled along the road of sustainable forest management.

Key words: criteria and indicators, forest management and conservation, forestry policy and legislation, sustained yield

INTRODUCTION

Sustainable Forest Management (SFM) is high on the list of issues for discussions at international forums. Since Malaysia is recognised as one of the major custodians of the world's tropical flora and fauna, (MCNEELY *et al.*, 1990) it naturally has to sustainably manage a wide range of tropical mega diversity to ensure prosperity. As such, the forest resources of Malaysia are managed not only for the production of wood and non-wood forest produce, but also for services such as safeguarding environmental stability, ensuring continual water supplies, minimising damage to rivers and agricultural land by flood and erosion control, and the conservation of biological diversity. Consequently striking the right balance between the production, conservation and protection functions of the forest is paramount, if the forest is to continue playing its economic, social, cultural and aesthetic roles.

All these would imply a deeper understanding of forest dynamics. This understanding is further complemented by research inputs, which may result in progressive improvement of sustainable forest management practices. In this respect, this approach is also in line with its commitment towards the ITTO Year 2000 Objective, whereby "all trade in tropical timber is sourced from sustainably managed forests by the year 2000" (ITTO, 1992).

It is indeed an honour for me to have the privilege to address such a distinguished audience of biologists, forest ecologists, conservation and environmental specialists, representatives from both public and private sectors, practising foresters, as well as NGOs. In this context, I have great pleasure to present to you my paper entitled "Malaysia's Quest Towards Sustainable Forest Management", through which I would like to share with you some of the experience we gained and the lessons we learnt in forest management and forest development, as we travel along the road of sustainable forest management.

FOREST MANAGEMENT STATUS

While is has been recognised that forests are resilient ecosystems, there are obviously limits to their ability to withstand environment change and man induced interference beyond which they will degrade (MAINI, 1992). Thus, understanding these limits will allow us to better define and strive towards Sustainable Forest Management (SFM), as the latter takes into consideration the elasticity of the forest ecosystem to withstand environmental changes, resulting from man induced interference to derive maximum benefits from this ecosystem (forest), which is forest management. As such, a cursory review of some of the critical factors of forest management, which can affect SFM may be in order. These include:

a) Forestry policy and legislation;
b) Economic and institutional framework;
c) Securing the forest resource base;

d) Sustained yield of forest produce;
e) Harvesting control;
f) Utilization;
g) Environmental factors;
h) Socio-economic considerations;
i) International co-operation;
l) Formulation of criteria and indicators.

Forestry policy and legislation

It has been recognised that a strong and continued political commitment at the highest level is indispensable for the attainment of SFM. This is particularly so in Malaysia where land is a state matter and is thus within the jurisdiction of the respective State Governments. Under the Malaysian Constitution, each of its 13 states is empowered to enact laws on forestry and to formulate forest policy independently. The executive authority of the Federal Government is only limited to providing advice and technical assistance to the states, training and the conduct of research and maintenance of experimental and demonstration stations.

Realising this and to facilitate the adoption of a coordinated and common approach to forestry, the National Forestry Council (NFC) was established in 1971 by the National Land Council (NLC). The NLC is empowered by the Malaysian Constitution to formulate policy for the promotion and control of utilization of land for mining, agriculture and forestry. On the other hand, the NFC serves as a forum for the Federal and the State Governments to discuss and solve common problems and issues relating to forestry policy, administration and management. Subsequently, a common forestry policy, namely the National Forestry Policy was adopted and implemented in 1978. Recent recognition of the importance of biological diversity, conservation, sustainable use of genetic resources, environmental protection and the role of the local communities in forest development and the promotion of eco-tourism has led to the revision of the National Forestry Policy in 1992. As such, the current National Forestry Policy 1978 (Revised 1992) contains all the pertinent points embodied in the ITTO Guidelines for SFM.

As forest legislation mirrors forest policy, it is only natural that such enactment be in place to provide legal backing to the National Forestry Policy in matters relating to administration, establishment of Permanent Reserved Forest (PRF), forest management and development, collection of royalties and premium, determining forest offences and imposition of penalties, and enforcement of law. In this context, Malaysia enacted the National Forestry Act 1984. This act was subsequently amended in 1993 to strengthen its provisions whereby severe penalties were imposed to deter forest offences, especially that of illegal logging.

The current legislation, National Forestry Act 1984 (amended in 1993) is a step forward towards achieving SFM, as they now embodied a vital change in the philosophy of forest management, no longer limited from just single use to multiple-use. Henceforth, forest management will be judged not just on the basis of the forest capacity to produce output in perpetuity, but more so on how the forests are managed to achieve the ever so delicate balance among its various functions. As we are now on the threshold of the 21st Century, the dictums of multiple–use functions will assume greater importance, particularly those pertaining to environment and conservation.

In this context, the elements of policy and legislative reforms are congruent with SFM principles, while their enforcement would offer better transparency and accountability towards achieving SFM.

Economic and institutional framework

Since SFM is still in its infancy, it is not possible to realise the increase in economic gain derived from the sale of forest produce from sustainably managed forest. Nevertheless, Malaysia recognised the need for SFM and has adopted an approach based on internationally recognised forest operations and auditing processes, implemented over large areas of the forest, while securing the resource base necessary for long term timber production. In this context, Malaysia has set aside a sum of US$ 10.1 million from its Timber Levy Fund to be used to finance SFM activities. Among the more notable improvements, the most noteworthy were in the areas of harvesting, replanting and public education in a more eco-friendly environment. Research also features prominently in SFM, whereby 17 projects relating to more environmental friendly forest management practices and preservation of wildlife are undertaken by the country's Forest Research Institute (FRIM).

Currently, an individual company has taken the initiative to have its forest produce certified by internationally recognised Third Party, as coming from sustainably managed forest. The forest produce fetches an increased premium of 10–13% over its normal selling price. This 'green premium' could be catalytic in encouraging private sectors' participation in the implementation of SFM.

To complement the economic framework, the need is felt to increase trained manpower to operate SFM in Malaysia. Currently, there are 4 major training schools for uniformed staff and 2 universities producing professional foresters. In addition, Sabah, Malaysia has prepared and initiated Reduced Impact Logging (RIL) guidelines and training on a regular basis. To date some 2,000 personnel from public and private sectors have been trained. The ITTO Model Forest Management Areas in Sarawak has also introduced RIL processes, including Low Impact Logging (LIL) using helicopters. Current initiatives in Peninsular Malaysia include a private sector use of a modified excavator for log extraction while FRIM together with Oikawa Motors Co. Ltd. (a Japanese Company) have just tested the mobile skyline yarding system in Trengganu. Similarly, officers from the Forestry Department Peninsular Malaysia (FDPM) have been trained in directional felling under a DANCED Project. A Mobile Training Unit has been set up and used on a regular basis to train tree fellers throughout the peninsula.

SECURING THE FOREST RESOURCE BASE

At the end of 1998, Malaysia's commitment to SFM is further enhanced by 20.25 million hectares (ha) or 61.4% of its total land under forest cover. Out of this, a total of 14.33 million has been designated as Permanent Reserved Forest (PRF) to be managed sustainably for the production of forest goods and services, which is compatible with the conservation of biological diversity, the protection of the environment, social and educational objectives. Of this total, an estimated 3.49 million hectares or 24.4% are classified as Protection Forest. In addition, an area of 2.12 million of forested land has been set aside as National/State Parks, Wildlife/Bird Sanctuaries, and Game/Nature Reserves, of which about 0.32 million ha are located within the PRF. Hence the total area under permanent forest cover in Malaysia is estimated to be 16.1 million ha or 46.9 % of its total land area.

Malaysia has also set aside virgin forest known as Virgin Jungle Reserves (VJR) throughout the country, to serve as permanent nature reserve and natural arboreta for comparing harvested and silviculturally treated forest, and as undisturbed natural forest for ecological and botanical studies. In this context, a total of 120 VJR, covering an area of 111,800 ha has been established. Having set aside sufficient areas of PRF, VJR, and having obtained forest legislation, rules, regulation and policy, Malaysia is now ready to implement SFM.

SUSTAINED YIELD OF FOREST PRODUCE

Under current legislation, it is mandatory to implement forest management plan, which among others governs the species to be removed, identifies the forest where logging is prohibited, imposes cutting limits, adheres to the Annual Allowed Cut (Annual Coupe), prescribes silvicultural treatments for harvested forest and identifies the need for infrastructure development.

Besides the forest management practices, much progress has also been made in forest inventory and data processing. This is reflected in following activities undertaken to assist Malaysia's approach towards SFM. These include:

a) National Forest Inventory (NFI) carried out over forested land on a 10 year cycle with the aim of determining the status and composition of the forest resources to enable more effective forest management planning.

b) Continuous Forest Inventory (CFI) undertaken in between the NFI, on a yearly basis to supplement and update the forest information collected during the NFI. Integrating both types of information will enhance forest management planning.

c) Pre-Felling Inventory (Pre-F) which enables the determination of the most effective forest management and silvicultural systems to be used, as well as to prescribe pre - felling silvicultural operations, with priority given to natural regeneration through the retention of adequate residual stand of advanced growth.

d) Growth and Yield Studies (G&Y) to determine the growth and mortality rates, as well as nutrient budget of forest harvested under the various cutting limits.

e) Forest Growth Simulation using Geographic Information System (GIS) to simulate forest growth and forecast timber production under different management regimes

f) GIS and Remote Sensing (RS) Technology to facilitate forest classification and to refine the existing forest classification methods in order to enhance SFM practices.

This evolvement of forest information technology not only provides better resource appraisal, but also enhances forest management practices towards SFM.

HARVESTING CONTROL

Control and regulation of forestry resources in Malaysia are tightly enforced so as to ensure the continuity of flow of forest produce using the Area Control Approach. This is done normally through the allocation of an annual felling coupe based on resources availability and current forest management practices over a five-yearly planning scheme.

In this context, Peninsular Malaysia has reduced its annual allowed cut over the years as reflected in the 5th (1986-1990), 6th (1991-1995) and 7th (1996-2000) Malaysia Plan, where 71,200, 52,250 and 46,040 ha were opened for logging, respectively. It is likely that for the duration of the 8th Malaysia Plan from 2001-2005, the areas to be opened will be established to around 45,000 ha, while taking into account the forest growth, harvesting damage (residues and the environment), mortality rates, amount of in–growth, natural regeneration and effectiveness of silvicultural treatments.

In addition, efforts are made to reduce harvesting damage through RIL and LIL, directional felling and 100% timber tagging of trees to be felled, marking of potential seed trees at 4 trees/ha above 30 cm \dbh., non–felling of Ficus, Parkia and snag trees, and leaving of buffer strips of between 3–5 m. along riverbanks. Adoption of Standard Road Specifications and Forest Management Guidelines are some of the other steps taken to further control harvesting while reducing damage to the environment. This practice of forest management follows the criteria and indicators of SFM.

UTILISATION

Trade wise log production declined to an average rate of 2.8% from 40.1 million cu. m. in 1990 to 31.2 mil. cu. m. in 1997. Due to the Asian financial crisis in 1998, log production fell by 9.5 mil. cu. m. (30,5%) from 1997 level.

With a stabilised land use pattern, fewer areas of conversion forest and pervasive application of SFM practices, it is envisaged that the supply of log will eventually be fixed at 21 mil. cu. m. annually from the PRF.

According to the 1998 statistics, Malaysia has 1,170 sawmills, 177 plywood/veneer mills, 12 blockboard plants, 9 fibreboard plants and over 3,007 furniture/wood working mills with an installed capacity of 24.4 mil. cu. m. and 10.7 mil cu. m. for sawmills and plywood/veneer mills, respectively. Log importation from the neighbouring countries will make up for the shortfall in local log supply and at the same time Malaysia is shifting from primary processing to secondary processing with emphasis on value-enhanced and finished products.

Environmental factors

To minimise the detrimental effects of forest harvesting on the environment, harvesting and all related infrastructure development in the PRF are carried out in accordance with the principles of SFM and the prescribed forest management and harvesting plans. This is done to ensure a sustainable level of log production with minimal damage to the residual stand, as well as to safeguard environmental quality and to maintain ecological balance. In addition, the harvesting of conversion forest is also coordinated and regulated to ensure its compliance to environmental standards and full resource utilisation.

Recognising the potential negative impacts of forest harvesting, the Environmental Quality Act 1974 was amended to include Environmental Impact Assessment (EIA) in 1985 and the order which came into force in 1987 prescribed activities that involved forest land uses listed therein.

Complementing the forest management and harvesting plans, various regulations and guidelines with special emphasis on environmental conservation have also been adopted. These include 'Forest Harvesting Guidelines', 'Forest Engineering Plan' and 'Standard Road Specifications'. These regulations and guidelines are incorporated into the harvesting licences while their implementation is closely supervised and monitored by the Forestry Department's staff.

In the hope of minimising the detrimental impacts of forest harvesting and of better managing the forest resources, Malaysia is currently exploring a number of reduced and low impact logging techniques including the use of skyline and helicopter logging systems.

Social and economic considerations

The forestry sector in Malaysia supports a significant number of people whose livelihood depends on the forest resource and its industry. A total of 225,826 people was directly employed by the forestry sector in 1998.

Overall, the total employment in the forestry sector had shown an increase of 27.4% between 1990 and 1998 with the plywood/veneer mills recording the highest increase in employment of 230.7%.

The total income generated through export earnings of forest and timber products, including rattan and wooden furniture in Malaysia in 1998 was RM 14.2 billion which constitutes 5.0% of the total export income of the country valued at RM 286.8 billion. In addition, a total of RM 1,085.8 million of forest revenue in the forms of royalty, silvicultural cess, premium and others was also collected from the forestry sector in Peninsular Malaysia and Sarawak in 1998.

The income and revenue collected are utilized for the socio-economic development of the country, as well as in upgrading services for the people. Besides providing direct employment and the generation of income and revenue, the forestry sector also contributes indirectly by supporting other service industries, such as packaging and eco-tourism.

A sizeable portion of the forest revenue collected is reinvested into the forest to carry out forest development and rehabilitation activities so as to enhance the growth of the residual stand. For example, the total amount of Silvicultural Cess collected in Peninsular Malaysia in 1998 was RM 35.3 million. Of this amount, a total of RM 29.5 million or 83.6% was utilized for forest development and rehabilitation works. In addition, the government has also allocated a sizeable fund under the Timber Export Levy Fund to carry out projects and studies aimed at ensuring and enhancing SFM in Malaysia.

Local community consultation

Being a multi-racial, multi-religious and democratic country, consultation and consensus building is a way of life in Malaysia. This is best reflected in the formation of consultative committees at village, district, state and federal levels to discuss and solve all matters pertaining to resources development.

In most instances, these consultation processes are required by law. A case in point is the constitution of any land as PRF, national park or wildlife sanctuary where the public will have to be notified and the affected communities consulted through hearings as provided for under the various legislations.

In addition, formal and informal consultations with local communities on forestry matters are also being carried out by logging operators, district officers and forestry department officials. Wherever appropriate the customary rights of the indigenous tribes are protected through expressed legal provisions and duly gazetted.

International co-operation

Apart from the national forestry development projects, Malaysia is also actively undertaking collaborative SFM projects in the field of forestry through international, regional and bilateral arrangements with various funding agencies. These projects are initiated in order to enhance the skills and capabilities of Malaysian foresters in forest resources planning, development and management, as well as in the

transfer of appropriate technology.
At the regional level, collaboration in forestry is implemented through the Association of South-East Asian Nations (ASEAN) administrative structure involving the following areas:
a) ASEAN common forestry policy;
b) Technical cooperation;
c) Forestry institutions;
d) Cooperation in intra-ASEAN timber trade;
e) ASEAN common stand on international issues on forestry.
International collaborative forestry projects are implemented through bilateral arrangements with funding countries/agencies. The bilateral projects currently being implemented in Malaysia include:
a) the various Malaysia-ITTO projects in the field of sustainable forest management, watershed management, rehabilitation, wildlife sanctuary and genetic resource conservation of commercial tree species in Malaysia.
b) the various Malaysia-German Technical Cooperation Programme (GTZ) on sustainable forest management and conservation in Peninsular Malaysia, Sabah and Sarawak.
c) Malaysia-EC projects on training of forest workers in Sabah.
d) Malaysia-Japan projects on multi-storied forest management, which aims to establish multi-storied forest management systems for the tropical forest.
e) The various Malaysia-Danish Cooperation for Environment and Development (DANCED) projects on sustainable management of peat swamp forests, preparation of an integrated management plan for Johor's Mangrove forest, as well as the study on extraction and possession of forest residues and small dimension logs.
f) Malaysia-the Netherlands projects on the documentation of scientific information on plant resources in order to develop a more comprehensive inventory of the country's forest resources, and the Forest Absorption of Carbon Emission (FACE) project which is concerned with the rehabilitation of logged-over areas in Sabah.

FORMULATION OF CRITERIA AND INDICATORS

A National Committee on SFM, supported by a Working Party comprising the 10 State Forestry Department in Peninsular Malaysia, was formed in 1994. The Committee had identified 92 activities to implement the ITTO's 5 criteria and 27 indicators on SFM at National level and 84 activities for implementation at Forest Management Unit (FMU) level or State level, 70out of them are identified to be at National level.
In Peninsular Malaysia, besides each of the activities identified at the National and FMU levels, the respective State Forestry Department had also formulated management specifications (benchmarks) for more effective monitoring and evaluation on the ground. Currently, a total of 206 and 191 management specifications have been formulated at the National and FMU levels, respectively. Of the 191 management specifications formulated at the FMU level, a total of 161 or 84 % of them are identical to those formulated at the National level.
For the purpose of Forest Management Certification at FMU level, Malaysia had also formulated 71 activities, and 164 management specification based on ITTO's 6 criteria and 28 indicators.
As certification entails an independent assessment as to whether forest management operation follows specific economic, social, environmental and ecological criteria, indicators, activities and management specifications, a National Timber Certification Council (NTCC) was established in 1998, as part of Malaysia's efforts to ensure SFM in Malaysia and to facilitate timber trade. The NTCC was involved in a number of consultative processes to formulate the Malaysian Criteria and Indicators (M C&I).
Externally, a third party assessor, the Netherlands through its Keurhout Foundation, had assessed current forest management practices in three Malaysian States aimed at achieving certification at the FMU level in 1996. The assessor issued "Audit Statements on Forest Management". A reassessment exercise was undertaken in 1998 that indicated an improvement in performance in all the three states.
An internal assessment procedure and a computer-aided monitoring system for assessing SFM based on the MC & I are now being developed with German (GTZ) assistance.
In Sabah, a forest certification exercise in the model management area in Deramakot Forest Reserve was conducted by SGS (M) Sdn, Bhd., an independent assessor with good results. The management concept and practices in Deramakot are in full compliance with the MC & I and hence the ITTO's Criteria and Indicators for SFM.

CONCLUSION

Recognising that sustainable management of the tropical forest resources is a complex and daunting task, the achievement of sustainability cannot be attained overnight nor are these goals static. On the contrary, the whole process is dynamic and evolving. As Malaysia remains committed to achieve SFM, definite steps are already in place to pave the way towards this direction, not withstanding the high cost of its implementation.
Nevertheless, Malaysia's commitment to SFM and the ITTO Year 2000 Objective is best reflected through her current achievements in the formulation of the comprehensive National Forestry Policy and the National Forestry Act, the establishment and publishing on gazette of PRF and a network of conservation areas, and the marked progress made in forestry research and development. It is further attested by bringing into operation and implementation of the Malaysian Criteria, Indicators, Activities Management Specifications for assessing SFM based on the elaboration of the ITTO's Criteria and Indicators for Sustainable Management of

Natural Tropical Forest, and the allocation of financial resources to carry out forest development activities, as well as bilateral and multi-lateral projects and studies related to sustainable management.
With all these in place, Malaysia is confident that it will achieve SFM within a given time frame and that the country will remain 'green' for future generations.

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RIASSUNTO - La Malesia è estremamente consapevole del bisogno di una efficace gestione e tutela delle risorse forestali, non solo per poterne assicurare una produzione sostenibile, ma anche per il bisogno di mantenere le funzioni svolte dalle foreste. Queste includono la salvaguardia ambientale, ma soprattutto la protezione della flora e della fauna che costituiscono un'inestimabile fonte di risorse genetiche per il miglioramento delle specie arboree indigene, delle colture agricole e del bestiame. Questo patrimonio di risorse rinnovabili continuerà ad essere gestito in base agli obiettivi ed alle priorità nazionali in modo da garantire al Paese di poter fruire dei benefici generati dalle foreste. L'impegno della Malesia nella gestione sostenibile delle foreste è attestato dalle correnti pratiche di gestione e sviluppo delle risorse forestali, dall'investimento di risorse finanziarie per poter effettuare queste attività, dallo sviluppo di progetti bilaterali di gestione forestale e dall'identificazione di criteri ed indicatori operativi per la valutazione della gestione sostenibile delle foreste. Questo lavoro presenta una revisione di questi approcci e descrive il livello raggiunto dalla Malesia nella gestione sostenibile delle foreste.

AUTHOR

Tuck Yuan Chin, Forestry Department Peninsular Malaysia, Jalan Sultan Salahuddin 50660 Kuala Lumpur, Malaysia

Forest use and implications of the 1998 logging ban in the Tibetan prefectures of Sichuan, China: a case study on forestry, reforestation and NTFP in Litang country, Ganzi Tap

D. WINKLER

ABSTRACT - This paper provides background on the China's Natural Forest Protection Project (NFPP) and the logging industry; it also assesses the impact of the logging ban on local people and administrations. Based on a case study from Litang County, Ganzi Tibetan Autonomous Prefectures, some of the challenges and opportunities arising from this recent policy change are presented. Of central interest are reforestation, the nursery sector and non-timber forest products (NTFP), especially the mushroom industry (*Tricholoma matsutake* and *Cordyceps sinensis*), which currently generates the largest share of local cash income. The ban offers opportunities to advance NTFP harvesting, processing and marketing, as well as the development of other sustainable resources, which have not received enough attention from development planners in the past. NFPP also provides the opportunity to improve local environmental conditions through forest restoration and revegetation of degraded slopes. Furthermore, former and present forestry practices fail to integrate local people in the state-run forestry sector, although this sector lends itself to community participation. To ensure long-term success local communities need to derive reliable and substantial economic benefits from the forestry sector.

Key words: China, forest products, forest protection, mushroom industry, revegetation

INTRODUCTION

Since the 1950s, the logging industry has served as the primary economic sector for the development of West Sichuan. The forests were viewed as an inexhaustible resource. The driving forces behind developing the logging industry were to deliver low cost timber to the timber deprived Chinese lowlands and to finance infrastructure development within the region. LI (1993) reports that West Sichuan's forest cover has decreased from 30% in the 1950s to 14% in the 1980s. This paper focuses on Sichuan's Ganzi ('Sino-Tibetan': Garzê) Tibetan Autonomous Prefecture (TAP), using Litang County as a case study . Most of the information presented has been collected by the author directly from forestry officials or natives in Ganzi TAP while consulting 'The Bridge Fund' (TBF) on a forest conservation and reforestation project in Litang County. In the 1980s the logging industry provided up to 70% of the cash revenue of many counties of West Sichuan (ZHAO, 1992), which are among the very poorest in the whole of PR China. Easily accessible forests were depleted within a few decades. Often state procurement logging quotas were 2 to 3 times higher than natural increments. In addition, forestry bureaus produced timber for the free market, often just to balance losses incurred from quota timber sales (ZHAO, 1992). Consequently, annual harvest including local consumption was estimated to reach nearly 5 times the natural growth (YANG, 1985) in neighbouring Aba (Sino-Tibetan: Ngawa) Tibetan & Qiang Autonomous Prefecture (TQAP). In addition, until the 1990s reforestation after clear cutting was a rare exception. In short, the opportunity to establish a sustainable forestry was missed and the logical consequence was either total resource exhaustion, as predicted by some (ZHAO, 1992), or substantial harvest reduction.

The logging ban as part of the natural forest protection program (NFPP)

In August 1998, PR China issued a logging ban in natural forests as part of the Natural Forest Protection Program (NFPP). Although official national statistics of the Ministry of Forestry (MoF) report an increase of forest area of 8.2% (from 12% to 13%) with a standing volume increase by 1.42% between 1980 and 1988, an analysis based on provincial-level MoF data reveals that the amount of land in timber production declined by 1%, while the volume decreased by 10.3% in the same period

(ALBERS *et al.*, 1998). This loss of volume was especially attributed to logging of old-growth forests in remote areas. Before the ban in 1997, MoF carried out a study, which revealed the severity of the economic and ecological crisis in state timber forests, which are predominately old-growth forests. The study suggested phasing out logging of natural forests by 2010 and shifting timber production to plantations, which would be required to adhere to sustainable harvesting regimes (HARKNESS, 1998). The devastating floods along the lower Yangtze in late summer of 1998 secured forest protection proponents the necessary political influence to implement serious counter measures. China is not alone in enacting a logging ban. In the 1990s full or partial bans on logging natural forests have become a common policy tool in Asia to combat high rates of deforestation and to protect critical remaining biodiversity. Natural forests have been withdrawn from commercial logging in all or parts of the Philippines, Thailand, Sri Lanka, India, Nepal, and China (APFC, 1999).

Although the NFPP applies to 18 provinces and autonomous regions in China (ZHANG, 2000), the focus of the logging ban is the headwaters of the Yellow River and especially the Yangtze. On the upper Yangtze, above the gigantic Three Gorges dam, which is currently under construction, all commercial timber harvesting in natural forests has been banned since Sept. 1, 1998 and will be in effect at least until 2010. According to China's National Bureau of Statistics the Chinese timber output plummeted 23.2% in the first nine months of 1999 to 16.64 million m^3. The NFPP also includes a major reforestation and revegetation component to reduce soil erosion. In 1998 the central government invested 4 billion RMB, in 1999 6 billion RMB and in 2000 7 billion (US$ 875 million). Timber production from natural forests was reduced from 32 million m^3 in 1997 to 29 million m^3 in 1998 and 23 million m^3 in 1999. In 2000 harvest is probably down to 14 million m^3 (ZHANG, 2000). According to Xinhua, the official Chinese news agency, the overall budget for the five upper Yangtze provinces (including Yunnan and Sichuan) and Tibet Autonomous Region (TAR), will be 120 billion RMB (US$ 14.5 billion); the government's goal is to increase their forest cover to 45% from the current 22% by 2020. The details of the NFPP are still being worked out. In fall 1999, Chinese Premier Zhu Rongji was on a fact-finding mission in affected areas including Sichuan's Aba TQAP. He announced the following five aspects of the new government policy. First, the government will cover the financial losses of local administrations caused by NFPP. Second, the forestry sector including the timber enterprises will be reformed. It is crucial to provide re-employment of state forest workers as planters and to provide financial support for those workers who must be laid-off. Third, sloped farmland needs to be re-vegetated and/or afforested; the government will compensate farmland losses with grains. Fourth, it is necessary to develop and implement effective reforestation and forest protection. Fifth, demand for wood products needs to be satisfied and rural firewood dependency reduced. Zhu Rongji also emphasized that the economic structure in the region must change. Tourism, forestry and animal husbandry must be developed at a fast speed. In 2000 the central government launched a major campaign called 'develop the West' (xibu kaifa). Presently, NFPP is being integrated in the 'Develop the West' program, which emphasizes economic development (i.e. mineral resource exploitation) and infrastructure improvements, such as road and communication improvements. Its aim is to reduce inequality between Han China and its western hinterland populated by other ethnic groups.

Presently, the logging ban is fully enforced and apparently is working in West Sichuan. While in June 1999 the roads where still jammed with trucks driving out the timber harvested before Sept. 1, 1998, already in October 1999 no more timber trucks from Sichuan were on the roads in Ganzi and Aba Prefecture. The only timber trucks encountered were from Tibet AR's Qamdo Prefecture. Although Tibet AR forest bureau had announced an interim logging ban for TAR in December 1998 (WINKLER, 1999, 2001), the logging has been resumed in the headwaters of the Mekong (Lancang Jiang / Dza Chu), Salween (Nu Jiang / Ngu Chu) and the Tsangpo / Brahmaputra (Yarlung Zangbo) but not in the three eastern TAR counties (Gonjo [Gongjue], Markam [Mangkang], and Jomda [Jiangda], all Qamdo Prefecture), which drain into the Yangtze. Qamdo (Changdu) and Nyingchi (Linzhi) prefectures of Tibet AR reportedly will implement an afforestation project at a cost of 300 million RMB with the help of the State Forestry Administration.

METHODOLOGY

The information and data contained in this paper, if not indicated otherwise, was collected by the author during five missions for The Bridge Fund (TBF) - A Project of The Philanthropic Collaborative, Inc., New York - to Ganzi TAP and Aba TAQP in 1999 and 2000. The author is consulting TBF on forestry and natural resources related projects in the Tibetan areas of Southwest China, including a reforestation and forest conservation project in Litang County, Ganzi TAP. In general TBF's projects aim at bettering the economic situation of local people. In the process of project preparation, implementation and monitoring countless meetings were held with officials from prefecture, county and township administrations. In addition, project sites were visited and whenever possible local people were interviewed.

CASE STUDY: LITANG COUNTRY

Litang (Tibetan: Li-Thang) County is located in the South of Ganzi Tibetan Autonomous Prefecture, Sichuan Province, SW-China. Nearly 95% of its 44,336 inhabitants are Tibetans (LOPD, 1998). In

1994, Litang had a gross domestic industrial and agricultural output of 67.03 million RMB; agriculture's mix of farming and pastoralism contributed 70.3%. Grain production, mainly barley, was 7487 tons; total number of livestock was 341,372. The industrial output consisted mostly of gold mining (72 kg) and timber (56,600 m^3 including 3800 m of sawed wood); government units run both sectors. The per capita income in pastoral areas was only 480.8 RMB. Litang County encompasses an area of 14,182 km^2. The county's altitude ranges from 2680 m to 6204 m, average altitude is 4200 m, treeline is at 4400 m. High-altitude grasslands alternate with deeply incised forested valleys. The climate is a temperate high mountain climate; over 80% of the annual precipitation (722 mm in Litang town at 4017 m) fall between June and September. The mean annual temperature in Litang Town is only 3.1°C. In Kyangba Township (Pinyin: Junba Xiang, 3400 m) it is estimated at 7°C.

Litang's main ecosystems are grasslands (42%), shrublands (33%), forests (13%), alpine rock and permafrost region (11%) and agricultural land (1%). Forests are dominated by conifers (*Pinus densata*, *Abies squamata*, *Picea balfouriana*, *Juniperus* spp.) and oaks (*Quercus aquifolioides*). Presently Litang has a closed forest cover of 11.6% (standing volume 35 Mm^3), however a total of 46% is classified as forest area, reflecting widespread forest degradation. Mostly secondary evergreen oak forests cover south-facing slopes; their conifers have been harvested or destroyed by repeated fire. Forest fires are a common threat (WINKLER, 2000, 2001). In April 1999 several hundred hectares burned in Litang's Gawa Xiang.

Logging and Forest Tenure

All commercial logging was stopped with the enactment of the NFPP in late 1998. Litang produced between 45,000 to 60,000 m^3 of quota timber annually since 1980. Annual timber consumption is figured at around 200,000 m^3, assuming a logging efficiency of 50% and including local firewood and construction wood consumption. Official figures for Litang report an annual firewood consumption of only 0.5m^3 per person (LOPD, 1997), whereas Han reports 1.22 m^3 from neighboring NW-Yunnan's forested high mountain areas. Including construction (0.28 m^3) and other household needs (0.21 m^3) annual wood consumption totals 1.71m^3 per person (LI, 1993). Besides being the county's main source of cash revenue, logging offered the opportunity of some extra cash income for locals. Commonly officials in Ganzi TAP quote that 20% of the locals' cash income is derived from manual labor in the forestry sector. However, most long-term forest workers are contracted from Sichuan's lowlands. Local employment has been restricted to mostly episodic, low paying manual tasks, such as logging, log transport, and slope clearing, which often coincided with agricultural work. Thus, these jobs are often not attractive to locals. Although rural households are depending on the forest resources, they are not dependent on the income opportunities from the logging industry. Their main livelihood is still based on the traditional subsistence herding and farming. Furthermore, in recent years their income was supplemented substantially by mushroom gathering, a much more lucrative activity .

While LFB members stated that 95% of Litang's forests are owned by the state, LOPD reports that 82% are state owned and 18% are collective forests. LIU (1994) reports that 35.2% of Litang's forests are community owned collective forests ('jitilin'), 64.8% are county state forests ('xianguoyou'). These contradicting sets of data reflect the fact that, although local communities are *de jure* owners of some forest areas, their ownership did neither entitle them to forest management nor to profiting from state timber exploitation. Thus, the distinction between state or community ownership did not affect exploitation. In Litang, as elsewhere in West Sichuan, commercial logging has been a state monopoly, carried out by provincial or county logging enterprises under the supervision of the respective forest bureau. Communities are not entitled to exploit timber resources beyond their own subsistence needs. Removal of timber requires an application to the forest bureau, which usually would grant permission. Disregarding this process would cause fines (WEN, 1999). According to Sichuan Province's NFPP (SPNFPP, 1998) locals will still be entitled to fulfill their subsistence need.

With the economic liberalization of the 1980s and the introduction of the household responsibility system elsewhere in China, a policy was instituted to transfer forest management decisions back to local communities (TAPP, 1996; ALBERS *et al.*, 1998; WEN, 1999). However, these changes have not reached Litang or other counties in the Tibetan areas so far. This is partially explainable by the absence of commercial timber extraction in most Tibetan communities before the 1950s. Yet, absence of commercial logging does not imply absence of traditional local forest management. YAN (1999) case study on traditional forest management in Gyarong (Pinyin: Jiarong) communities (Barkam / Maerkang County, Aba TQAP) clearly indicates otherwise, as does LUO *et al.*'s (1999) study from Deqen TAP (NW Yunnan).

In comparison, the management of the pastoral sector has already been transferred back to households in Litang in the 1980s, yet without transferring land ownership back to local communities. Pasturelands are not privately or community owned, but *de jure* state owned, yet households have grazing rights. Recent policies are aiming at changing the ownership status of pastoral land in Litang. LFB officials were stating that clearly defined land ownership would result in an adaptation of herd size to the actual carrying capacity of the herder's pasture. However, the present settling of formerly mobile pastoralists is already accompanied by pasture degradation and erosion around their new homesteads, caused by all-year-round grazing of the fragile high altitude pastureland.

Reforestation and the nursery sector

In spring 1999, the first planting season after the logging ban enactment, considerable resources of Litang Forest Bureau (LFB) were tied up in removing timber cut the year before. There was no increase in the area reforested yet. No extra funding as part of the NFPP had reached Litang for the planting season. However, in spring 2000 LFB received 2.1 million RMB from the central government, out of which 1.5 million RMB were earmarked for reforestation of 733 ha. The overall reforested area in 2000 comprised 800 ha, out of which 67 ha were financed by The Bridge Fund. Reforestation efforts were clearly stepped up in all of West Sichuan in 2000. Increased reforestation efforts are causing a shortage in seedlings, which will last for another 5 years, since seedlings need 3 to 5 years before they can be planted out. In the past Litang bought 50% of its 1.5 million annually planted seedlings from outside sources, the other 50% were grown in Litang itself. 80% of the acquired seedlings were obtained from Luhuo nursery (Luhuo/Zhaggo County), Ganzi TAP's head nursery, which has an annual output of 3 million spruces. There is a demand for 5 to 6 million seedlings. Not surprisingly, prices for spruce seedlings increased by 30% to 0.21 RMB per seedling in 1999. Presently, Luhuo, just like Litang and other nurseries in Ganzi, produces only spruces (*Picea balfouriana, P. retroflexa*) for reforestation of cold-temperate subalpine forests, as outlined by prefectural regulations. Spruce is preferred due to the higher value of its timber and its resistance to disease, especially stem rot. North-facing slopes, which have been mainly exploited, contain a high percentage of fir (*Abies squamata, A. ernestii*) and sometimes some larch (*Larix mastersiana*).

The present paradigm shift in China away from perceiving forest as a sole source of timber to a multipurpose ecosystem as expressed in the current emphasis on protection of natural forests offers the opportunity to diversify the species base in reforestation to minimize potential biodiversity loss when restoring forests (HARKNESS, 1998; STUDLEY, 1999). Although, species diversification has not been integrated in new regulations in Ganzi TAP yet, officials seem receptive to the concept. However, prefectural forestry regulations require only the propagation of spruce due to its more valuable timber and disease resistance. So far, attempts to widen the conifer species base have failed in Litang County. Other major nursery species are poplar (*Populus kangdingensis*) used commonly around settlements and along streams and shrub willows (*Salix* spp.) for soil stabilization. LFB carried out a huge poplar plantation comprising tens of hectares on the grasslands to the West of Litang Town (4000m). The plantation failed due to livestock impact. There was no fencing. Smaller fenced in plantations succeeded close by. Pine (*Pinus densata*) is used for afforestation and reforestation in warm-temperate valleys, along the region's major rivers.

Fencing reforestation plots is very uncommon, due to its high costs. Moreover, fencing is only efficient when it is fully accepted by locals. One opening renders any fence worthless. As PENG JITAI (pers. comm., 1999) pointed out "Curiously, in Tibetan areas, it is not livestock that gets fenced in but everything that needs to be protected from livestock". In Litang, instead of fencing, planters insert a wooden batten tripod around the seedling to protect it from livestock trampling and biting. Also sometimes seedling density is increased from 200 seedlings per mu (3000 per ha), the prefectural (and national) minimum requirement, to 300 - 500 seedlings per mu (4500 - 7500 per ha) to account for future losses from high grazing pressure. Also killed seedlings are being replaced in consecutive years. Evidently, high seedling densities substantially increase reforestation costs. However, in many places none of these countermeasures are being taken and seedling survival rates are substantially reduced. Also, sometimes the new emphasis on reforestation seems to spur irrational conifer planting on prime grazing areas along roads instead of carrying out reforestation on degraded slopes, which only have shrub vegetation left.

Reforestation, grazing and local participation

The Sichuan government had announced the closing of nearly 90,000 km^2 to livestock grazing, which equals a third of West Sichuan's area in August 1998. However, in Litang there have been no efforts to actually close off freshly reforested slopes. In early June 1999, while planting was underway, yaks were grazing the slopes. A point in case is Kyangba's Balong Valley (3700 m), which was clearcut in the early 1990s and reforested in 1993. In 1999, this north-facing slope was densely crisscrossed by livestock paths. Perennials well adapted to grazing (i.e. *Hallenia, Gentiana*), as well as a strong element of thorny shrubs (*Berberis, Rosa*), clearly indicated grazing pressure. The spruce seedlings were impacted by biting (goats) and trampling (yaks), although they had been protected by tripods when planted. Six years later most of the tripods had disintegrated. Very few seedlings displayed straight monopodial growth typical for conifers. Most seedlings, now about 10 years old, had reached only 30 to 40cm in height. It can be assumed that these slopes have been grazed before logging, since they are relatively close to permanent settlements. Other sites in more remote areas indicate less intense grazing. However, herders follow the logging roads and move their livestock into areas previously not grazed, often closer to their villages than the pastures above treeline. Some of these areas have been closed off successfully, after LFB destroyed logging road bridges.

When the issue of grazing of reforestation plots was brought up with locals in Kyangba, they informed the author that fresh clearcuts are some of their best grazing areas. It would take very serious government pressure and full financial compensation to stop them from grazing their livestock there. Not surprisingly, so far LFB tolerates grazing reforestation plots and clearly shies away from grazing restrictions. Disputes over grazing rights have great potential for stirring up serious conflicts, since the availability of grazing ground is the basic requirement for traditional livestock herding. Grazing disputes sometimes turn violent. This was the case over an unclear county line above Kyangba between Litang and Nyagrong (Pinyin: Xinlong) County in fall 1999.

In the early 1980s, village committees selected individuals who were assigned as forest and wildlife guards. Local guards were paid an annual fee of 0.75 RMB per hectare. Initially this approach was perceived as successful by forestry officials. However, the rate has neither been raised nor adjusted for inflation. Thus, it is now not enough to secure the guards' dedication. Officials suggested the rate would need to be 5 - 10 RMB/ha/a. So far, no funds have been assigned to finance such an initiative for Ganzi's 1,870,000 ha of forest area.

LFB is trying to develop new strategies in their outreach program. LFB invited Buddhist leaders, many of whom hold positions within the local administrations, to participate in a TBF sponsored training on forest protection and reforestation. The Forestry Bureau is cooperating with these lamas to reach the local Tibetan population, who highly respect Buddhist leaders. Traditional Buddhist views emphasize the sacredness of all life, non-violence, and the importance of the forests for the well being of all sentient beings. Thus, they are perfectly suited to promote wildlife and forest protection. LFB hopes that this innovative approach will help popularize reforestation as well as wildlife and forest conservation with local people. This new approach will definitely enhance LFB's efforts to improve their outreach to local people.

In order to receive genuine local cooperation for successful and efficient reforestation and forest conservation it is crucial that local people derive clear benefits from these activities. Ecosystem services of the forests are not sufficient to bring about a change in the attitude of locals. Livestock herding is the base of their livelihood. From a herder's perspective there is no doubt, herd survival is more important than seedling survival, especially since in the long run seedlings will render grazing grounds useless. Herders will not forego grazing clearcuts unless they will participate in economic terms in forestry. Only if these seedlings will present an investment in the future of their own community and secure direct economic benefits, will locals change their attitude. In Litang, TBF is committed to facilitate training for locals, so that they are better prepared to participate in the forestry sector. However, training locals as forest workers seems to some forestry officials a far-fetched idea, especially regarding the present surplus of forest bureau employees who used to work as loggers. LFB seems mostly concerned with providing employment for its former workers of the timber extraction units, which had to give up operation after the logging ban. Not surprisingly, discussing reforestation in Kyangba, villagers stated that they "rather plant fruit trees than conifers." This is very logical, since there is no direct economic benefit for them under present forestry management. The benefits of the logging stayed with government agencies. Kyangba Township records from Oct. 1998 figure the direct income of locals (1847 people) from forestry at 8,700 RMB (only 0.49% of their overall annual income), while the county made at least 1.3 million RMB on Junba timber in 1997 (39 RMB per m^3). Returns, such as infrastructure services, catered mostly to the needs of the logging industry and their workers, which were Han Chinese contracted from the Sichuan lowlands.

Thus, for successful reforestation it is paramount to reform the present policy and guarantee locals adequate economic benefits. So far, the concept of integrating locals into the forestry sector to assure their support for reforestation has not fully caught on in Litang and elsewhere in the region. Community forestry or local participation beyond simple manual labor input are currently neither practiced nor discussed. TBF is committed to facilitate training for locals, so that they can better participate in the forestry sector. Successful reforestation will not be achievable without assuring support from locals. Herders can only become stewards of the forests if forestry is part of their livelihood generation. Otherwise, the strategy of turning forests into pastures, practiced since time immemorial in Tibetan areas, will be continued (WINKLER, 1996, 2000) on an even higher rate with the unintentional support of the forestry bureaus.

NFPP and its impact on local people and administrations

Having described the role of locals in the logging industry, it is not surprising that the negative impact on locals, whose existence is still based on traditional subsistence production, is not dramatic thus far. The income opportunities generated by logging are being replaced by reforestation activities. The logging ban offers the opportunity for reforming a non-integrated forest industry. Still, local people will be adversely affected by the fact that local administrations, be it on prefectural, county or township level, lost one of their main sources of revenue. For example, the county revenue in Songpan was reduced 64% (about 7 million RMB) in 1999, while locals only lost 13% of their income due to the logging ban (LÜ, 1999). However the loss of revenue on the county level will negatively impact maintenance and development of infrastructure, such as schools, medical facilities and roads, which are still lagging very far behind other rural areas in China. It is apparent that new dependency on outside financial support will ensue. Funds for reforestation alone will not be able to mitigate the fiscal crisis.

In addition, in the 1990s Litang county has developed a timber producing factory in Qionglai (50km SW of Chengdu), which produces floorboards and doorframes with precision tools imported from Europe. These investments are now highly endangered, since Litang County can not supply its own timber anymore. Direct investments in timber processing facilities in remote counties such as Litang are otherwise marginal. However, a few counties developed timber-related industries other than sawmills, which only consumed a small fraction of the annual cut. All of these jobs are at risk, since timber has run out already. In Barkam (Pinyin: Maerkang) town (Barkam County, Aba TQAP) for example, Xueshan Furniture factory, which was started in the 1970s and had an annual output of goods of more than 10 million RMB, had to close down its operation in 1999. Over one hundred workers, who were hired on contract, lost their jobs completely. Another 50 'lifetime' employees have been retrained and now work as tree planters. Not surprisingly, several local officials have expressed the wish that the necessary timber for these few industries within their counties should be excluded. Each county could have a certain allocation of timber for local commercial processing. This suggestion is feasible, since the ban on transport of raw and sawn timber, usually monitored at timber check points at county lines, would be maintained. Transport of finished timber based products could be excluded. The development of local timber related cottage industries producing furniture, window frames, floorboards, etc. should be supported at least in a later stage of the NFPP. Such an industry could be effective in advocating sustainable harvesting rates, since local resource exhaustion would eliminate its economic base. High transport costs for importing timber would undermine its competitiveness due to its remoteness. In addition, the trucking industry, where many trucks are privately owned, and its related businesses, such as lodges, small restaurants, and improvised teashops, will be negatively affected by the logging ban.

Besides initiating a transformation of the logging industry towards sustainable forestry and catching up with reforestation, the logging ban offers the opportunity to focus development initiatives and business on other sustainable natural resources. Many of them have been managed sustainably in the past as part of land-use practices aiming at subsistence. Generating a cash income was not essential to survival. However, the collapse of traditional barter exchange, and the advent of consumer goods, created the need for generating a cash income, thus spreading market oriented production. Traditional subsistence management practices of natural resources are being replaced by market oriented management. Often, management based on indigenous knowledge systems, which had a certain degree of sustainability, is being replaced by more intense management, where knowledge of sustainability is not yet available. Here, cooperation between scientists, development planners and local communities is essential to ensure sustainability for future generations.

Fungus and plant trade

For centuries Tibetans have collected and traded medicinal plants used in Tibetan Medicine (TM) and Traditional Chinese Medicine (TCM). Many medicinal plants are used in both systems, however plants used in TCM dominate the market, since many more people rely on TCM than TM. The early western explorers ROCKHILL (1891), BACOT (1912) and COALES (1919) mention the export of medicinal plants from Tibetan areas to lowland China, often traded for tea. COALES (1919) reported on trade in Tachienlu: "The medicines exported are mainly rhubarb and other vegetable drugs for the Chinese market".

Resources control, be it usage rights or ownership, are crucial factors in accessing and developing economic plant and fungus resources. While logging benefits stayed with government agencies, benefits from plant and mushroom harvesting, carried out mainly by locals, are staying with local households. The income from mushroom trade is currently more important to many households in the Tibetan areas than the benefits from the forestry industry. In Kyangba, *Tricholoma* together with *Cordyceps* are providing 60% of the locals' cash income.

Resource allocation for the development of this industry, which would enable households to realize even higher and more reliable profits, remains marginal in comparison to forestry or mining industries. One of the reasons that locals are able to profit considerably from this industry seems to be the fact that after the commune phase of the 1960s and 70s, government agencies returned the plant and mushroom trade to households. Otherwise government quotas would require households to sell certain amounts of gathered plants to government agencies for fixed prices, which are usually significantly below market prices (SCHWARTZ, 1998; LAFITTE, 1999). The downside is that households do not receive the necessary support to organize themselves in order to achieve a more powerful position in selling their harvest. Thus, a substantial part of the profits remains with a few intermediate dealers and goes to companies in the Chinese lowlands or abroad in East Asia. Only a fraction of the economic plants are currently packaged and marketed from within the Tibetan areas. The majority of plants are still 'exported' as raw materials. Other than a few exceptions, the opportunity to establish brands within the area of origination has so far been missed. Resources need to be allocated to foster this process to boost local economies and maximize benefits for locals.

Mushrooms trade

Trade of caterpillar fungus (*Cordyceps sinensis*) and matsutake (*Tricholoma matsutake*, but also *T. quercicola* and *T. bakamatsutake*) is presently the most important source of cash income for local people. The culinary mushroom market presently focuses on matsutake, but there is a great variety, local sources indicate nearly 100 species, of other highly valuable mushrooms. Many of these mushrooms are also marketed in China. Only a few in other parts of the world. Traditionally the culinary mushroom market was dominated by *Auricularia auricula* (tree ear, Pinyin: mu'er). DAI (1994) reports an average harvest of 5,000 kg before the mid 1980s. Currently king bolete (*Boletus edulis*) and other boletes (*Boletus* spp., *Leccinum* spp.), chanterelles (*Cantharellus* spp.) are also being bought by some mushroom dealers, but their economic potential is not fully utilized yet. Hedgehog (*Hydnum repandum*), Scaly tooth (*Sarcodon imbricatus*), corals (*Ramaria* spp.), to name a few, are collected and sold for local consumption. In spring there is a market for morels (*Morchella* spp.) and basket stinkhorn (*Dictyophora indusiata*).

Cordyceps sinensis

COALES (1919) makes early mention of the caterpillar fungus trade: "The most interesting is the curious Chungtsao [Pinyin: chongcao] or insect grass, a dried caterpillar about 2 inches [5cm] long, which has been killed by a fungus of about the same length growing out of one of its segments. It is supposed to be an excellent restorative to weak constitutions". Yertsa Gonba, as Tibetans know it, is a high-altitude grassland fungus parasitizing on the larvae of a small white butterfly, *Hepialus armoricanus* (DAI, 1994). It occurs in alpine areas between 3000 m to 5000 m (LIU, 1994; DORJE, 1995), however most commonly between 3800 m to 4500 m. In Litang County, collectors are confined in gathering to their legal grazing grounds or to the forests they have usage rights for. Outsiders have to pay a fee to the local community for the right of collection. One group reported that they had to pay a seasonal fee of 25 RMB per person for *Cordyceps* gathering. Not surprisingly, there are also reports of conflicts between locals and unlicensed intruders.

The output of *Cordyceps*, which is collected in early spring in all grasslands across the Tibetan Plateau, is substantial. Estimates by local dealers and officials for the present annual harvest in Litang have ranged up to 5,000 kg, representing around 5 to 10 million specimens. Their local market value is 10 to 15 million RMB in Litang. Even, if these production estimates are too high, they are not completely out of proportion. For comparison, according to Liu (1994), old statistics for Xikang Province report a *Cordyceps* harvest of 15,000 kg in 1939. Between 1949 and the mid-1980s annual *Cordyceps* harvest ranged between 5,000 and 20,000 kg in Ganzi Prefecture (DAI, 1994).

Tricholoma matsutake

Many of the *Cordyceps* dealers also deal in *Tricholoma matsutake*. In the 1990s, the trade in culinary mushrooms has exploded all over the southeast of the Tibetan Plateau. The market is driven by *Tricholoma* (Pinyin: songrong), known in English as 'pine mushroom', the translation of its Japanese name 'matsutake'. It is Japan's most highly prized mushroom. It is also popular in lowland China and Korea. Matsutake is a forest fungus. In the forest region of the Tibetan Plateau, it grows in mycorrhyzial symbiosis with pines (*Pinus densata*, *P. yunnanensis*) and evergreen oaks (*Quercus* spp. sec. *semecarpifolia*) in the montane and subalpine level. Here its fruiting season is in summer.

Although local people store *Tricholoma*, it is most valuable fresh. Thus, *Tricholoma* requires quick transportation. Furthermore, the main market is in Japan and the trade is dominated by Chinese-Japanese joint ventures. In Ganzi Prefecture, some of these companies are now sending out refrigerated trucks to the hinterland, collecting the harvests on a daily base and bringing them to Chengdu. Also, in source areas such as Litang and neighbouring Nyagchuka (Pinyin: Yajiang) mushrooms are sorted and stored in refrigerated warehouses before transport. For transport, ice is packed with the mushrooms. More refrigerated warehouses are closely located to the Chengdu airport, from where they are sent off by air to their market destinations. The recent rise in disposable cash income through the mushroom trade is most easily detected in a recent construction boom of farmhouses in traditional Tibetan style all over the distribution area. In neighboring Nyagquka County (Ganzi TAP), along the main highway, many farmhouses are being now mudded and even painted in color, both novelties for homesteads in the region. In addition, many farmhouses now boost satellite dishes on their traditional flat-roofs.

Until the 1980s, around 75 t of *Tricholoma* were annually harvested in Ganzi Prefecture (DAI, 1994), then the export market took off. For the 1990s, Lu (1998) reports an annual harvest of 400-500 t for West Sichuan, generating an income of 4.8 - 6 million US$ for farmers and the same profit for the foreign trading companies. Local governments earn 0.7 -1.2 million US$ in resource charges and taxes. In the record year of 1998, 50,000 kg of songrong were collected in Kyangba district's oak forests (NORBU, PAN, 1998). In an average year in Nyagchuka County 100 t of Matsutake is harvested and exported. In 2000 mushroom checkpoints were established along the main highway in south Ganzi Prefecture. Nyagchuka County collected a 23% tax on *Tricholoma* in 2000.

The fact that annual fruiting fluctuates highly is problematic for local people. Many fungi have multiannual fruiting cycles, and are very sensitive to a variety of climatic factors, especially quantity and timing of precipitation as well the temperature regimes. Consequently, matsutake is experiencing extreme price fluctuations within a collection area through the years. Price fluctuations are somewhat mitigated by the fact that there is a direct correlation between availability of mushrooms and its value. Thus, to a certain degree, low prices are compensated by abundance. However, price fluctuations are further enhanced by bumper harvests elsewhere in the Northern Hemisphere, which affect the international market, often causing seasonal price fluctuations. Moreover, the market is also impacted by economic developments in consumer countries. The

current economic crisis in Japan and other Asian countries has caused a slowdown in price development for gourmet mushrooms.
In 1999, a year with a relative poor harvest, 1 kg of fresh local songrong was sold for 144-160 RMB in Litang town. In 1998, a record year in Litang, prices fell to their absolute minimum. In Litang town, 1 kg sold for only 10-20 RMB. In Kyangba Xian, mushroom dealers paid local collectors only 8 RMB/kg. Mushrooms are bought up by a handful of motorized dealers, who take the fresh crop to a main market place. The price increases between Kyangba and Litang (65 km apart on a poor road) by 75%. This is very profitable business. The main market place is usually the county town, where mushrooms are bought by the international trading companies to be taken to the next airport.
There is no scientific evidence that present harvesting rates are either sustainable or unsustainable. Multi-annual fruiting requires long-term data collection. LU (1999) reports that in the 1980s the yield of songrong was 1000 t in West Sichuan, but that it has decreased to 500 t in the 1990s. Some concerned local governments have reacted by initiating a rotating system of harvest. In this system, locals can only collect once in three years. However, PILZ (1997) estimates that even in intensively harvested areas in Oregon State, USA, 50% of the matsutake are consumed by wildlife, are not found, or become too mature or defective for commercial collection before they are found. Still, mechanisms should be established, such as minimum sizes and maximum age limits to ensure picking practices, which minimize negative impact on the sustainability of matsutake. In addition, forest health is a very decisive factor in matsutake fruiting afforestation and reforestation, if the appropriate tree species are planted, may lead to future matsutake fruiting, usually 40 years hence (PILZ., 1997). Many Tibetans can not participate or only derive reduced benefits from the current forest fungi trade, since wide areas have been deforested in the past to create pasture land or have been cut recently for timber production (WINKLER, 1998).

Medicinal plants

The most important medicinal plant parts collected in Litang are bulbs of *Fritillaria* spp. (TCM: Beimu), and roots of *Rheum* spp. (TCM: Dahuang) and *Astragalus* spp. (TCM: Huangqi). Rhubarb (*Rheum*) is a very conspicuous high mountain plant growing above 3700m. It is collected in Litang in October and November. In addition, great amounts of fritillary bulbs are collected in autumn. *Astragalus* root is dug in lower elevations in spring. Sustainability of present harvesting rates is not always secured, but since many of these plants have been collected over a long period, local collectors have established a harvesting regime, which allows plant regeneration. In Litang, all medicinal plants are collected from the wild, although some growing operations have developed elsewhere. Medicinal plant cultivation could create new income sources and reduce the pressure on wild populations. Furthermore, the present focus on the development and improvement of the nursery sector could also serve as a way for transferring horticultural skills for medicinal plant production. For example, conifer nurseries in Heilongjiang Province, NE China, improved their income substantially through ginseng (*Panax ginseng*) cultivation (RICHARDSON, 1990).
More income potential needs to be developed locally. Preparing a product ready for marketing and establishing brands would increase local profit margins and create job opportunities. So far, almost all the packaging, including canning, and marketing, be it in the mushroom or medicinal herb sector, is done in the lowlands. Only a small amount of mushrooms is dried clean enough to be sold in profitable outside markets. If the processing were carried out within the Tibetan areas, local communities would derive higher benefits.

Fruit and nut trees

Fruit and nut tree cultivation, including apple, pear, apricot, and walnut, has also produced good results in the region. Ganzi TAP forest bureau launched a fruit tree initiative in 2000. Walnut and apple production is especially suited for Litang's valleys below 3400 m. Walnut has the great advantage of not being sensitive to transportation. Fruit and nut tree cultivation is still in very early stages in Litang. It is common in certain counties with better developed outreach programs, like Luhuo and Kangding. Fruit trees can be planted in agricultural areas, which are already fenced. Villagers in Kyangba suggested that degraded areas around settlements should be restored with orchards rather than conifer plantations. Another beneficial 'fruit tree' is seabuckthorn (*Hippophae* spp., Pinyin: shaji, Tibetan: tarbu), a small deciduous native tree or shrub that can fix nitrogen. It tolerates drought, flood, and extreme temperatures. Seabuckthorn berries and seeds have great nutritional and medicinal value. A tasty juice can be extracted from the berries, which is being produced in Li County (Tibetan: Tashi Ling) near Barkam and marketed in Aba Prefecture. Extensive research has already been carried out in China (LU, 1992). In addition, it is very useful to fight erosion and restore degraded lands. All these qualities make it a natural choice for environmental restoration. Also of interest is the deciduous tree *Eucommia ulmoides* (Pinyin: Dozhong). Its bark is used in TCM as well as an important source of latex for industrial use.

CONCLUSION

The logging ban finally halted resource overexploitation, but is creating economic hardships for government agencies and units, the administration and industries. It is evident that the impoverished local administration will have to face a new dependency on subsidies. Least directly affected will be the average farmer and herder household in Litang whose existence is still based on traditional subsistence production and who supplements its cash income through the 'NTFP' sector. Economic liberalization and increased national and international trade have created the opportunity for locals to generate a substantial income through mushroom gathering.

The dominance of an often inflexible state sector, its focus on logging and mining for government revenue generation, in connection with bad communication, have slowed the development of sustainable ecosystem-based resources. Many of these economic activities fill niches and are only slowly becoming the target of development planners. Even a key industry such as forestry is just being transformed to economic and ecological sustainability through outside intervention. This seems belated, since forestry has been managed as a community based and sustainable industry elsewhere in China since the mid 1980s (WEN, 1999).

Non-timber forest products, fruit and nut tree cultivation, and other sustainable resources will now receive more attention and will need to be developed to improve the local income base. Here, matching funds from international aid organizations can be of great importance. Technical assistance can support the development of ecologically better adapted forestry and natural resource management. Moreover, the development of NTFP will establish further the value of forest ecosystems beyond their timber value, before logging is resumed.

The ban is only the beginning, a 'time-out' to rethink the situation and establish a base for sustainable management. The chance to establish a sustainable forest industry has been missed and it will take many decades until the forests recover, since it takes about 100 years for subalpine conifer forests to mature. Consequently, a logging ban of 13 years is only the beginning of forest restoration. The Natural Forest Protection Project's logging ban and its reforestation initiative offer the opportunity to reevaluate present management strategies creating the context to implement necessary reforms in forest management. Successful, efficient reforestation requires local cooperation on a participatory basis, reaching far beyond present manual labor inputs. For Litang County, it offers the opportunity to diversify an economy based on gold mining and logging. Now, the need for sustainable, locally based development of Litang's economic sectors is even more urgent. Last, but not least, the NFPP creates the opportunity to initiate truly participatory forest management, so that locals will finally benefit from the rich forest resources and regain some control over their resources.

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RIASSUNTO – Questo lavoro fornisce le informazioni relative al Natural Forest Protection Project (NFPP) cinese ed all'industria del legno; inoltre esso valuta l'impatto del divieto di taglio sulla popolazione e sull'amministrazione locale. Il lavoro, basato sul caso di studio del Litang County, prefettura autonoma tibetana di Ganzi, presenta le problematiche e le opportunità che discendono dal recente cambiamento della politica forestale. Di centrale interesse sono la riforestazione, il settore vivaistico ed i prodotti forestali non-legnosi (NTFP), in particolar modo l'industria micologica (*Tricholoma matsutake* e *Cordyceps sinensis*) che costituisce la principale fonte di reddito locale. Il divieto offre l'opportunità di far progredire la filiera del NTFP (raccolta, lavorazione e marketing), così come lo sviluppo sostenibile di altre risorse che non hanno ricevuto particolare attenzione nel modello di sviluppo passato. Il NFPP dà anche l'opportunità di migliorare le condizioni ambientali locali attraverso i programmi di recupero e di rivegetazione dei pendii degradati. Inoltre, sia le pratiche forestali passate che quelle correnti non sono riuscite ad integrare le persone locali nel settore forestale statale, sebbene questo settore implichi una partecipazione comunitaria. Per assicurare il successo nel lungo termine, le comunità locali devono trarre benefici economici sicuri e sostanziali dal settore forestale.

AUTHOR

Daniel Winkler, 7840 126th Ave NE, Kirkland WA 98033, USA

Development of criteria and indicators for sustainable forest management in China

W.F. XIAO, S.G. ZHANG and Z.P. JIANG

ABSTRACT - The criteria and indicators (C&I) is a tool to assess the status of forest management and also a framework of monitoring and assessing the change of sustainable forest management with time. Based on the research done in three typical forest regions, 8 criteria and 80 indicators have been established at national level in China. However, there are difficulties to establish a unified C&I for the whole country, because of the huge differences in climate, geography, forest types and distribution, and social and economic development existing in China. Large obstacles, such as data logging and evaluation, fund availability, technical support, and possibility of applying C&I, are evident in all aspects. Technical assistance and fund support are extremely important for developing an effective C&I of sustainable forest management in China.

Key words: criteria and indicators, forest protection, sustainable forest management

INTRODUCTION

A national forest resources inventory conducted between 1995 and 1999 has revealed a forest cover of 158.941 million hectares, only 16.55% of the total land area of China, and the total growing stock of forest resources is 12,490 million cubic meters. The natural forests in the north-east province are the most extensive forest area comprising the largest industrial wood resources in the country . Other important forests are natural forests in the southwest and plantations in the southern provinces. Forest ownership is mixed, about 45.3% of the total forest cover is state land and administered by the State Forestry Administration, and 54.7% is collective-owned although managed under the authority of forest laws and monitored by the State Forestry Administration (STATE FORESTRY ADMINISTRATION, 1995). Forestry activities are a source of intensive labour and the sector is a large employer of both men and women, over 2.5 million employees.

China is one of the most diverse species countries in the world. There are about 32,800 flowering plant species, of which 9,410 are wood species or 40% of the total in the world. The forest and other vegetation are home to about 499 species of mammals, 1,244 species of birds, 391 species of reptiles, 280 species of amphibians, and millions of invertebrates. Furthermore, China is one of the three major centers of origin of cultivated plants in the world, with a number of related wild species.

China's forest cover is 5% of the total world forest area and contrasts sharply with the relatively high Chinese population that is more than 20% of the world's population. The country is facing a worsening imbalance between supply and demand for wood products, particularly for wood of commercial value, stimulated in part by the government's economic development policies (JIANG, 1996). A national survey of wood supply and consumption patterns indicated that by 2010 the consumption will reach 180 million cubic meters for commercial log and 80 million cubic meters for fuel wood, leaving a large wood deficit. The supply-demand gap for wood excluding fuel wood is expected to increase to about 60 million cubic meters over the next decade. Meanwhile, there are 179 million hectares of water-eroded area and 262 million hectares of desertification-prone land that need to be controlled in the country, accounting to 18.6% and 27.3% of the territory respectively. Up to 15-20% of the total number of fauna and flora species , including more than 4,000 flowering plants and about 400 species are being endangered or threatened and need to be protected.

However, China is fully aware of its obligations and potential roles in protection of the global ecosystems and environment (GUAN, 1998). Realizing that forests are a main part of the land ecosystem and occupy an irreplaceable predominant position in the global environmental conservation and development, the Chinese government has placed high priority upon sustainable forestry development (SHEN, 1997). Since 1990s, the government has taken a series of significant measures in promoting sustainable forest management. Important activities include the formulation and implementation of a serious key programme and policies, such as the Forestry Action Plan for China's Agenda 21, the outline of China Ecological Development Program, the Action Plan of Protection of Biodiversity in China, as well as relevant researches, building capacity and extension (JIANG, 1996).

The development goal for China's 2010 forestry is that the forestry comprehensive strength can be comparable to that of countries with medium forest development level (LI, 1996). The objectives are:

a) The forest coverage increases from current 13.92% to 17.5%, and the growing stock from 11.79 billion cubic meters to 12.96 billion cubic meters;
b) The shelterbelt system becomes desirable with a perfect distribution pattern and starts to function well in environment improving. The area of desertified land controlled accounts 11.43 million hectares, or 7.4% of the total area, and the controlled area suffering from soil and water erosion reaches 37.02 million hectares, or 20.8% of the total area. All the farmland in plains has shelterbelt networks. The area of all types of natural reserves, including wetland, increases from the present 51.26 million hectares to 70.68 million hectares, taking up 7.36% of the territory;
c) Reasonable economic forests and fuel wood forests are established where appropriate. The total output of timber increases from current 127 million cubic meters to 159 million cubic meters, and the total output value of forestry industries from 180 billion RMB yuan to 1056 billion RMB yuan with a growth rate of 13%. Forest product industries make big progresses, especially those of wood-based panels, sawing timber, forest chemicals, wood pulp and papermaking, wood chips, and bamboo products.

In recent years, about 5 million hectares are planted on an average each year in China, of which over 1 million hectares are established by aerial seeding. The man-made forests cover 34.25 million hectares, or 26.7% of the total forest land. The government has taken the strict control of logging quotas as the central element of forest management, on the principle that annual removal of timber forest should not exceed its annual growth. The damage rate of forest fires has dropped from 0.8% in 1987 down to the present 0.2%, while the integrated treatment rate has remarkably risen from 36.7% in the early 1980s up to the current 70%. Since 1978, twelve major forest conservation programs have been implemented which cover 705.6 million hectares or 73.5% of territory. There are 116.8 million hectares of planned program area for afforestation, which are located in the fragile ecotones including soil and water erosion area, desertification-prone land, and salty lowland or wetland. The Three North Shelterbelt systems focus on wind erosion problems in the northwest, central north, and northeast regions. Extensive soil and water conservation afforestation continues to be implemented along the upper and central sections of the Yangtze river and Yellow river, in the coastal shelterbelt system, in the Taihangshan mountainous, in the farmland shelterbelt network in plain areas, and in the natural forest protection areas. More than 22 million hectares have been established.

China is actively involved in the international sustainable forest management (SFM) drive especially the Montreal process, while searching its own way to sustainable forestry, and it will be continued in technological exchanges and cooperation (ZHANG, 1999). All these reflect the sincerity and determination of the Chinese government and people towards achieving SFM or optimum forest management (ZHU *et al.*, 1998).

SFM CRITERIA AND INDICATORS AT NATIONAL LEVEL IN CHINA

The development of criteria and indicators (C&I) for forest protection and sustainable management is an important step in implementing the Forestry Action Plan for China's Agenda 21, a blueprint for China's forestry towards 21st century (LI, 1996). It is essential to formulate China's C&I on the basis of its specific conditions, although there are 8 regional processes going on in the world, including the Montreal process, the Helsinki process, the ITTO process, etc. In 1995, a research group was set up to work out the C&I for sustainable forest management in China (ZHANG, 1999). Under the leadership of the State Forestry Administration, formulation of C&I was put into effect by the Sustainable Forestry Research Center of the Chinese Academy of Forestry (STATE FORESTRY ADMINISTRATION, 1995). Through the involvement of experts from various fields, a provisional framework for C&I for protection and sustainable management of China's forests has been worked out , and it is now being tested and perfected. (SHEN, 1997).

The formulation of C&I in China, following three principles of unanimous, feasible and operational commitment, is required to meet Chinese specific conditions, while keeping in line with the international trends of development. It is mainly in the light of the C&I framework adopted by Montreal process. The overall status delineation at national level mainly concentrates on the process of developing C&I definitions, taking account of the wide differences of population density, social and economic status and natural setting, and their status of forest types, quality and quantity of forest resources and management level in the various areas in China (LEI, 1996). The implementation and monitoring, testing plan and data collection tools of indicators should be based on the specific conditions in the various areas.

There are 8 criteria and 80 indicators in the framework for C&I for protection and sustainable management of China's forests. Of the indicators, 11 are ready to be implemented, 55 require some research and development, 9 require long-term research and development, and 5 are uncertain. It indicates that it is urgent to develop techniques and means for identification of indicator, testing and data collection.

Four problems have been identified in China's framework for SFM C&I (ZHU *et al.*, 1998):

a) Some indicators need to be well defined, some are too general such as the indicator 6.1.5, while others too specific such as indicators 5.6-5.7 and indicators 7.3.1-7.3.7;
b) Some indicators need to be combined based on the relationship among indicators;
c) Some terms are difficult to apply, such as the significantly deviated from historic range of variation' in indicators 3.3 & 4.4, five or ten years instead may be more applicable;
d) Lack of techniques and means for monitoring and testing of indicators.

A simple comparison between the Montreal process and China's framework of C&I showed that:

a) Their C&I structures are quite similar. There are 50 indicators shared by the two frameworks, of which 8 are in criteria one, 5 in criteria two, 3 in criteria three, 5 in criteria four, 3 in criteria five, 9 in criteria six, 9 in criteria seven, and 8 in criteria eight.
b) Criterion 7 in Montreal process is divided into criteria 7-8 in China's framework, because some indicators belong to social science while others to technology.
c) The indicator 6.5 'employment' and 6.3 'social benefits' in Montreal process is included in indicators 6.1 and 6.3 in China's framework respectively.
d) More indicators for soil & water conservation and investment of forestry in China's framework, while more for multiple benefits in Montreal process.

SFM CRITERIA AND INDICATORS AT SUB-NATIONAL LEVEL IN CHINA

China has developed its C&I at two sub-national levels, i.e. the regional level and forest management unit (FMU) level (ZHANG, 1999). An FMU occupies a geographical area from a forest farm to compartment. However, there are different opinions on how to define a region; for example, someone proposed that a region is basically a watershed, while others suggested that it is an administrative unit. It is reasonable that a C&I at regional level should be developed on the basis of forest zones defined by the most recently up-dated forestry zones in China.

As China is a country with vast territory and rich diversity of forest types, the C&I at sub-national levels should be more specific to the local situations, deleting or adding indicators accordingly, within the national framework. An Indicator, which is not measurable at sub-national levels, should be cancelled, although it is important at national level. For example, the forest contribution to global weather has no significance at a small scale. Furthermore, to make an effective evaluation by C&I at national level, it is necessary to weigh each indicator at subnational level according to the local objectives of forest management (ZHANG, 1999).

Since 1997, the identification and testing of C&I at regional level have been conducted in three typical forestry zones, i.e. Yichun of Heilongjiang province, Zhangye of Gansu province, and Fenyi of Jiangxi province, each is representative of the northeastern state forestry zone, northwest dry land forestry zone, and south collective forestry zone respectively. It is also funded by the UNDP project building capacity , research and extension for sustainable forest management (SHEN, 1997). A number of experts, both national and international, have been involved.

The draft C&I at regional level developed for the three typical forestry zones are very similar to that at national level, each has 8 criteria (Tab. 1, Tab. 2). There are 77 indicators defined for Yichun with much concern on the maintenance of forest productivity, 68 for Zhangye with high priority on environmental and social issues and by forest types (water conservation forest, farmland shelterbelt, and tree crop plantation), and 60 for Fenyi with attention on forest ownership, plantations, and tree crops.

There are 8 typical sites selected from the demonstration forest network (Tab. 3), for feasibility study of C&I and revising ranges of indicator.s Most FMU indicators are developed within criteria 1-4. Furthermore, formulating C&I for tropical forest is a component of the ITTO cooperation project in Hainan province.

DEMONSTRATION FOREST NETWORK

Six trends could be identified in the country's forest management strategies:

- Conservation of biodiversity gets high priority in forest management practices;
- Man-made forests will become the most important source of timber production;
- Natural forests will be gradually protected, especially those in the upper and middle reaches of rivers and watersheds;
- Production basis for timber will move from temperate northeastern regions to subtropical southern provinces, although the exploitation of forests in the southwest region will be speeded up provided the assurance of environmental safety of the region;
- Shelterbelt systems focused on soil and water conservation continue to be highly important, especially those in the vast arid and semi-arid areas, in the farmland areas in the plains, and in the coastal zones; and
- Non-wood products will be placed into the agenda of forest management.

China is one of earliest countries in building capacity , research and extension for SFM in the world (ZHU *et al.*, 1998). Since 1997, a demonstration for-

TABLE 1

Indicators at regional level (sub-national) in three typical forest zones.
Indicatori a livello regionale (sub-nazionale) in tre tipiche zone forestali.

Criterion	National Indicators	Sub-national Indicators		
		Fenyi Jiangxi	Zhangye Gansu	Yichun Heilogjiang
C1 Biodiversity	10	11	13	9
1.1 Ecosystem	6	6	9	4
1.2 Species	2	3	2	2
1.3 Genetics	2	2	2	3
C2 Productivity	8	9	8	12
C3 Health & Vitality	3	3	8	3
C4 Soil & Water	14	11	8	8
C5 Carbon cycles	8	3	4	5
C6 Multiple benefits	12	9	10	14
6.1 Growing & Consumption	7	4	7	9
6.2 Investment of Forestry	3	4	2	3
6.3 Recreation, culture, social etc.	2	1	1	2
C7 Legal & Policy	17	10	10	18
7.1 Legislation	5	3	3	8
7.2 Policy	4	3	3	6
7.3 Economic framework	8	4	4	4
C8 Information & Technology	8	4	7	8
8.1 Measurement & Monitoring	3	1	3	3
8.2 Research & Development	5	3	4	5
Total	80	60	68	77

TABLE 2

Comparison between regional and national indicators in China.
Confronto tra gli indicatori regionali e nazionali in Cina.

	CRITERION	C1	C2	C3	C4	C5	C6	C7	C8	Total
Jiangxi	Indicators shared	6	5	2	8	4	6	9	4	44
	% national total	60.0	62.5	66.7	57.1	50.0	50.0	52.9	50.0	55.0
Gansu	Indicators shared	6	3	2	4	4	5	9	7	40
	% national total	60.0	37.5	66.7	28.6	50.0	41.7	52.9	87.5	50.0
Heilongjiang	Indicators shared	7	8	1	7	4	10	8	8	54
	% national total	70.0	100	33.3	50.0	50.0	83.3	47.1	100	67.5

est network for SFM has been established. It is made up of 8 sample sites that are located in Heilongjiang, Hebei, Gansu, Jiangxi, Zhejiang, and Guangdong provinces. More recently, Linan site in Zhejiang has further become one part of the International Model Forest Network for SFM initiated by Canada.

The aim of the demonstration forest network is to find a way to sustainable forestry development by relevant research, technique improvement, and extension (LI, 1996). So far, a model SFM plan has been worked out for each site through investigation, analysis, and discussions. The identification and testing of C&I at sub-national level have been conducted in the network as mentioned above. Meanwhile, extensive technical training has also been carried out at various levels.

FUTURE COOPERATION WITH MONTREAL PROCESS COUNTRIES

Under the circumstances of obtaining international granted funds, the Chinese government is willing to have a wide range of cooperation in the following fields with the Montreal process countries:

- Exchanges and cooperation between China and

TABLE 3
Demonstration forest network for sustainable forest management in China.
Network delle foreste guida per la gestione sostenibile delle foreste in Cina.

Forest Zone	Location	Years	Issues focused
1. NE State Forestry Zone	Yichun, Heilongjiang	1997-	Protection of natural forest
	Mulin, Heilongjiang	1997-	Development of large state forest bureaus
2. Three-North Dryland Forestry Zone	Zhangye, Gansu	1997-	Management of water conservation
	Pingshan, Hebei	1997-	Forest Sustainable mountainous development
3. Plain Farmland Forestry Zone	Non defined	Non defined	Non defined
4. Collective Forestry Zones	Fenyi, Jiangxi	1997-	Collective-owned forest management
5. Eleven S.P. Forestry Zone	Tonggu, Jiangxi	1997-	Plantation management
6. U&M Yangtze Forestry Zone	Lin'an, Zhejiang	1998-	Sustainable mountainous development
7. Coastal Forestry Zone	Zhanjiang, Guangdong	1997-	Forestry and forest industry
8. NW Sub-alpine Forestry Zone	Non defined	Non defined	Non defined
9. Tropical Forestry Zone	Hainan	1992-	Tropical forest management
10. Tibet No-Forestry Zone	Non defined	Non defined	Non defined

the other Montreal process countries.
- Researches on sustainable forest management in temperate, subtropical and arid/semi-arid regions.
- Establishment of an Asian Research, Development and Training Center on sustainable forest management.
- Development of criteria and indicators at subnational level for sustainable forest management;
- Monitoring and evaluation of the C&I, including the system of information collection, analysis and exchanges;
- Forest ecosystem characteristics and function, and accounting systems and methodologies to measure and integrate forest values;
- Theory and technology for establishment and management of protected forest, especially for combating desertification, natural forest protection, and biodiversity conservation;
- Theory and technology for sustainable forest management, including the forest ecosystem management and participatory forest management;
- Establishment of regional integrate research, information network, and training organization;
- Evaluation and application of traditional knowledge of forestry.

RECOMMENDATIONS
- Efforts should be made among Montreal process countries to develop the common definitions of some key terms and concepts for forest management and forest resource assessment.
- Research and information exchanges are necessary among Montreal process countries because of inadequate relevant knowledge and techniques for SFM criteria and indicators.
- For better reporting in 2000 and 2003, it is necessary to encourage bilateral or trilateral activities or cooperation, both informal and formal, among MP countries.
- It is essential to promote communication among MP countries by utilizing existing Internet, however, it should also be encouraged to translate and apply the important documents of MPWG and its TAC.
- Capacity building is an important issue for SFM, it is suggested to establish an MP research, development, and training center and its regional centers. China will be interested in being invoved in those activities, such as research project, information and personnel exchanges.
- Traditional knowledge is for SFM. It should be reasonably summarized, evaluated, and utilized. China has accumulated a number of traditional knowledge, and is, willing to engage in further cooperation based on equality and mutual benefit with the other MP countries.
- Establishment of an MP fund on research and development, to promote researches on SFM and personnel training.
- Establishing an MP demonstration forest network, and starting contact with the International Model Forest Network.

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RIASSUNTO - I criteri e gli indicatori (C&I) costituiscono sia uno strumento per valutare lo stato della gestione forestale, sia una struttura di monitoraggio e di valutazione dei cambiamenti nel tempo della gestione sostenibile delle foreste. Otto criteri ed 80 indicatori sono stati istituiti a livello nazionale in Cina sulla scorta di ricerche effettuate in tre foreste tipiche. Esistono però una serie di problemi per stabilire un modello unificato di C&I per l'intero Paese, a causa delle enormi differenze esistenti in Cina nel clima, nella geografia, nel tipo e distribuzione delle foreste e nello sviluppo socio-economico. Ciò determina la presenza di una serie di grandi ostacoli da superare, come ad esempio la raccolta e la valutazione dei dati, la disponibilità di fondi, l'assistenza tecnica e la reale possibilità di attuare i C&I. L'assistenza tecnica e il sostegno economico sono di estrema importanza per lo sviluppo di C&I efficaci per la gestione sostenibile delle foreste in Cina.

AUTHORS

Wen Fa Xiao, Shou Gong Zhang, Ze Ping Jiang, Sustainable Forestry Development Research Center, P.O. Box 67, Chinese Academy of Forestry, Beijing, 100091, P.R.China