PERFORMANCE OF SMALLHOLDER TEAK PLANTATIONS (*TECTONA GRANDIS*) IN XISHUANGBANNA, SOUTH-WEST CHINA

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LANGENBERGER G & LIU J. 2013. Performance of smallholder teak plantations (*Tectona grandis*) in Xishuangbanna, South-West China. Teak is the most important high grade wood cultivated in plantations, representing 7% of tropical hardwood plantations. Due to its perceived value and fast growth rate, teak may be a suitable complement in smallholder land management systems diversifying production and income base for farmers. This paper presents performance data of smallholder teak stands in South-West (SW) China and compares them with data on similarly aged plantations and smallholder teak stands on a global scale. To that end we analysed a set of 18 smallholder stands in SW China and conducted a literature review on comparable studies. Unfortunately, our survey showed remarkable lack of published data. Besides general references stating quality problems in smallholder stands we could not find a single study presenting detailed analysis. Smallholder teak stands in SW China showed ambivalent results. While the average growth rate was high, and, from an international perspective, ranged in the upper end of similarly aged plantations, stem shape and quality were poor, which would negatively affect grading of stems after harvest. Therefore, although teak might contribute to the diversification of smallholders' product portfolio, an active management would be required to realise the economic potential of the timber.

Keywords: Forking, quality features, management, economic potential

LANGENBERGER G & LIU J. 2013. Prestasi ladang pokok jati (*Tectona grandis*) pekebun kecil di Xishuangbanna, Barat Daya China. Kayu jati ialah kayu gred tinggi yang paling penting ditanam di ladang. Ladang jati merangkumi 7% daripada ladang kayu keras tropika. Oleh sebab nilai serta kadar pertumbuhannya yang tinggi, jati mungkin sesuai dipertimbangkan dalam sistem pengurusan tanah pekebun kecil untuk mempelbagaikan hasil serta pendapatan pekebun. Kertas kerja ini melaporkan data prestasi dirian jati pekebun kecil di Barat Daya China dan membandingkannya dengan data daripada ladang yang seusia dengannya serta dirian pekebun kecil di seluruh dunia. Untuk ini, kami menganalisis 18 dirian pekebun kecil Barat Daya China selain membuat sorotan kajian yang sesuai. Malangnya, tinjauan kami menunjukkan betapa kurangnya data yang diterbitkan. Selain rujukan umum yang membincangkan masalah dirian pekebun kecil, kami tidak menjumpai sebarang analisis terperinci. Dirian jati pekebun kecil di Barat Daya China menunjukkan keputusan yang tidak tuntas. Walaupun kadar pertumbuhannya tinggi dan setara dengan nilai antarabangsa bagi ladang yang sama usia, secara keseluruhan bentuk serta kualiti batang adalah rendah mutunya. Ini sudah pasti mempengaruhi dengan teruk penggredan batang selepas dituai. Justeru, walaupun jati mungkin menyumbang kepada kepelbagaian hasil pekebun kecil, pengurusan aktif masih diperlukan untuk merealisasikan potensi ekonominya.

INTRODUCTION

Decreasing natural timber resources have resulted in increasing interest in forest plantations as an efficient timber source and a means to reduce pressure on natural forests. The contribution of plantations to global forest cover in 2006 was 3.8% of the total area of forests (FAO 2006). The majority of plantation species, be it hardwood such as *Acacia* and *Eucalyptus* species, or softwood such as *Pinus* species, produce commodity timber in short rotation cycles of up to 30 years (Christersson & Verma 2006). These species cannot replace the valuable timbers still in demand which are mainly extracted from natural or semi-natural forests. Currently only few high priced hardwood species are cultivated in plantations and at a considerable scale, namely,

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rosewood (*Dalbergia sissoo*), mahogany (*Swietenia macrophylla*) and teak (*Tectona grandis*). Teak is the most widely grown with an area of 4% in all tropical plantations and 7% in tropical hardwood plantations (FAO 2001). Outside its native range in India, Lao People Democratic Republic (PDR), Myanmar and Thailand, teak is grown in all tropical and subtropical regions around the globe, in Africa, Central and South America, the Caribbean, Pacific Islands and northern Australia (Pandey & Brown 2000).

Requiring substantial investments, plantations are usually of considerable size and economic importance. Accordingly, the interest in obtaining performance data is high and the necessary funding to conduct analytical studies is available. Therefore, performance data of large-scale teak plantations are available from a variety of sources (e.g. Bermejo et al. 2004, Pérez 2005). However, due to its valuable timber and high growth rate, teak is also of interest to smallholders and has thus been promoted as alternative income source for rural people by governments and development agencies (Midgley et al. 2007, Newby et al. 2012).

This is important against the background of the expansion of rubber monocultures in the region. Although rubber (*Hevea brasiliensis*) cultivation presents a profitable opportunity for smallholders, the reliance on a single tree crop implies a higher liability to climatic, disease and economic risks. Teak could contribute to a diversification of the production and development of multifunctional farming systems.

The objective of this paper was to assess and evaluate the performance of smallholder teak based on analysis of 18 stands in South-West (SW) China. Data obtained were compared with data of larger-scale plantations and smallholders found in the literature.

MATERIALS AND METHODS

Background and general approach

Based on our observations on smallholder teak plantations in the framework of a research project on landuse cover change in SW China (https://lilac.uni-hohenheim.de), we decided to conduct a performance analysis of the plantations and compare results obtained with available literature on a global scale. Besides the in-situ evaluation, we conducted a literature search using the following search terms: smallholder teak, quality, bifurcation and forking. We reviewed relevant literature relating to stem quality, namely, stem form, branching and forking, and obvious damages and wounds which strongly affected the selling price of timber (Pramono et al. 2011, Kollert & Cherubini 2012).

There was no documentation on teak promotion in our research area, e.g. source of planting material, acceptance by farmers, location and extent of established stands or technical success rates. Nevertheless, we learned from local farmers and nature reserve staff that teak had been introduced by a development cooperation project implemented by the then German Agency for Technical Cooperation (GTZ, now German Agency for International Cooperation—GIZ) as income generating and livelihood improvement activity around the year 2000. The planting material was bought by the project from the Xishuangbanna Tropical Botanical Garden in Menglun and a nursery which was not specified. The genetic origin of the planting stock is unclear. All farmers claimed that they did not receive any technical information or training on the management of teak, nor did they have a clear understanding of quality features, marketing potential or possible buyers. The farmers also mentioned that there was no follow up by the project after the teak had been planted.

Geographical location of smallholder stands

The analysis of teak stands was conducted at the Naban River Watershed National Nature Reserve (22° 04'–22° 17' N, 100° 32'–100° 44' E) in the Xishuangbanna Dai Autonomous Prefecture, Yunnan Province, China in March and April 2010, at the end of the dry season. Although the prefecture borders Lao PDR and Myanmar, teak is not indigenous to the area. The nature reserve covers an area of 267 km^2 and extends over an altitudinal range from 539 to 2304 m above sea level. It comprises 1219 households with a population of 5538 people in 32 villages, belonging to five ethnic groups (Wu & Yang 2006).

The geology and parent material in the eastern part of the nature reserve where teak has been planted are mainly Phyllites. Soils belong

to the red soils category of the Chinese Soil Classification (Wolff & Zhang 2010). The local climate is typical monsoon with dry season from November till April accounting for an average of 230 mm of precipitation, and rainy season from May till October with 1400 mm of precipitation, adding up to an average annual total of 1630 mm. The average annual temperatures range from 18 to 22 °C. Occasionally, temperature can drop below 0 °C (Wu & Yang 2006).

Sampling procedure

After screening the occurrence of teak within the nature reserve, 18 stands in six villages were selected to represent the variability of smallholder plantations within the reserve with regard to elevation, ownership and individual management. The following stand parameters were also documented: aspect and slope, total number of trees, row spacing and tree spacing within the rows (distance between the trees) and, where available, the year of planting. Based on these data the actual stand size and tree density were calculated. Baseline data for the selected 18 stands are presented in Table 1.

The standard procedure for stand establishment consists of row planting along contour lines. In each stand, we sampled a maximum of 20 trees. Thus, all stands of up to 20 trees were fully inventoried, each tree representing a sampling unit. Stands with more than 20 trees were stratified considering the first (upper slope), middle (middle slope) and last (lower slope) rows. These three rows were selected to represent the heterogeneity in the plantations. Seven trees each from the first and last rows and six from the middle row were selected for assessment. If the rows contained enough trees, every other tree, beginning with the second tree in each row, was selected until the 7^{th} or 6^{th} (for the middle row) sample tree. If rows were too short to take every other tree, subsequent trees were taken, also starting from the second tree in the row. Thus, within the 18 stands, 339 (28.8%) from a total of 1178 trees were assessed

Growth as well as form and quality of stem were assessed for each tree. For growth performance, we measured tree height and circumference at breast height (1.3 m) above bark using a tape measure and a clinometer respectively. The circumference was converted to diameter at breast height (dbh) value. Quality assessment comprised the following major features and defects:

(1) stem shape: straight, not straight
(2) forking: present/absent; height of forking
(3) branching: height to first branch; branch diameter at conjunction with main stem (horizontally measured), expressed in three classes: 1 = 0–5 cm, 2 = > 5–10 cm, 3 = > 10 cm
(4) stem damages: only natural causes were taken into account, damages such as cuts by machete or bark damages caused by ropes to fix cattle were disregarded; we distinguished between open wounds and pronounced thickenings of the stem, usually surrounding the whole stem ('ring swellings'); a causal analysis of damages was not conducted since this was out of our scope.

Data processing and graph design were carried out using MS Excel and Sigma Plot. To visualise the stand data we used box plots; boxes indicated the 25^{th} and 75^{th} percentiles and the whiskers, the 10^{th} and 90^{th} percentiles. All outliers were included.

RESULTS

The potential of teak as an income source for smallholders is stressed in practically all publications found on that issue. Unfortunately, they are mainly grey literature, i.e. publications lacking in scientific review. Therefore, the quality of data as well as the power of argumentation was difficult to assess. There is the general observation that smallholder teak stands lack management inputs in terms of thinning, pruning and removal of poor quality stems, thus, compromising potential income prospects (Midgley et al. 2007, Pramono et al. 2011). While the general impact of short rotation management on timber properties such as wood density and strength as well as visual features (colour and grain) received considerable attention (Pérez & Kanninnen 2005), evaluation of external properties was difficult to find, although they were important in trading (Midgley et al. 2007). Very few studies dealt with such features (Piotto et al. 2003, Hansen et al. 2005, Mollick et al. 2005), and none presented a substantial analysis of smallholder stand features. A scientifically-based analysis of economic consequences of poor management in smallholder teak stands is therefore needed.

Table 1 Baseline data of inventoried teak stands in the Naban River Watershed National Nature Reserve

No.	Village	Owner	Elevation (m)	Year of establishment	Spacing* (m × m)	Growing space per tree (m^2)	No. of trees in total	Stand size (m^2)	No of trees per hectare
1	A Ma Lao Zhai	Li Yonghe and Yin Luwei	692	2001	3 × 2	6	35	210	1667
2	A Ma Lao Zhai	Li Laosan	687	2000–2002	5 × 3	15	115	1725	667
3	A Ma Lao Zhai	Li Yongping and Yin Lufang	689	2000–2002	5 × 2.5	12,5	99	1237,5	800
4	A Ma Lao Zhai	Li Damei, Li Xueliang and Lao Tie	715	2000–2002	5 × 3	15	300	4500	667
5	A Ma Lao Zhai	Ma Dinghong	840	2000	5 × 2.5	12,5	30	375	800
6	Beng Long	Wang Laosi	951	2002	7 × 4	28	44	1232	357
7	Da Nuo You	Dao Jinghua	881	2000–2002	6 × 4	24	16	384	417
8	Da Nuo You	Da Fusheng	802	2000–2002	5 × 3	15	100	1500	667
9	Da Nuo You	Zha Na	786	2000–2002	6 × 4	24	50	1200	417
10	Hui Lao	Zha Mo	828	2000–2002	5 × 3	15	39	585	667
11	Man Dian	Ai Xiang1	682	2000–2002	0 × 2	Row planting	16	-	-
12	Man Dian	Ai Xiang2	675	2000–2002	6 × 5	30	64	1920	333
13	Man Dian	Ai Xiang1	695	2000–2002	2.5 × 2	5	14	70	2000
14	Man Dian	Ai La	691	2000–2002	5 × 3	15	27	405	667
15	Man Dian	Ai Han	686	2000–2002	5 × 2.5	10	100	1000	1000
16	Na Ban	Ai Dang	678	2002	3 × 3	9	13	117	1111
17	Na Ban	Ai Han Long	675	2002	2 × 2.5	5	68	340	2000
18	Na Ban	Ai Han Nuai	715	2001	3 × 3	9	48	432	1111

*Row distance × distance of trees within the row; range in the year of establishment shows that no exact year is defined

Smallholder teak stands in the Naban River Watershed National Nature Reserve

Stand establishment in the Naban River Watershed National Nature Reserve turned out to be very heterogeneous in all respects. According to the farmers, seedlings were 70–90 cm when planted. Planting took place in 2000 till 2002, making the stands 7 to 9 years old when assessed. Unfortunately, the exact figures on the year of establishment could not be obtained for all stands. Therefore, we presented the stand data without distinguishing between years, and, additionally, provided within all graphs clustered averages for the 18 stands. There was no clear correlation between age and growth performance, which would have been expected if site conditions and management were homogeneous.

No management measures except weeding have been applied to the studied stands. Therefore, it could be safely concluded that the observed spacing represented the planting scheme. Both stand size and spacing varied considerably between different stands and owners. Row distance ranged from 2 to 7 m, and distance of trees within rows from 2 to 5 m. The respective growing space per tree thus ranged from 5 to 28 m^2, i.e. equivalent to 2000 and 333 trees ha^{-1} respectively (Table 1).

Growth parameters

Average tree height for all 18 stands was 16.2 m, ranging from 12.8 to 19.5 m (Figure 1). Given that the stand age was between 7 and 9 years, average annual height growth of all 18 stands was 1.8 to 2.3 m. Dbh ranged from 11.9 to 22.6 cm, with an average of 17.1 cm (Figure 2). The respective annual diameter increase was between 1.9 and 2.4 cm. Height/dbh value of a tree, which expresses the relationship between height of the tree and its dbh, provides a very good indicator for its stability against wind and storm damage. The lower the value, the higher the stability of the tree and the higher the value, the higher the risk of wind throw and wind break. Height/dbh values of measured trees in this study ranged from 71 to 114, with an average of 94 (Figure 3). These were reasonable good figures for trees of that young even-aged stands. From our experience, we conclude that height/dbh values for solitary trees above 80 or 90 are susceptible to wind break and wind throw while those below that value are quite resistant. For even-aged young

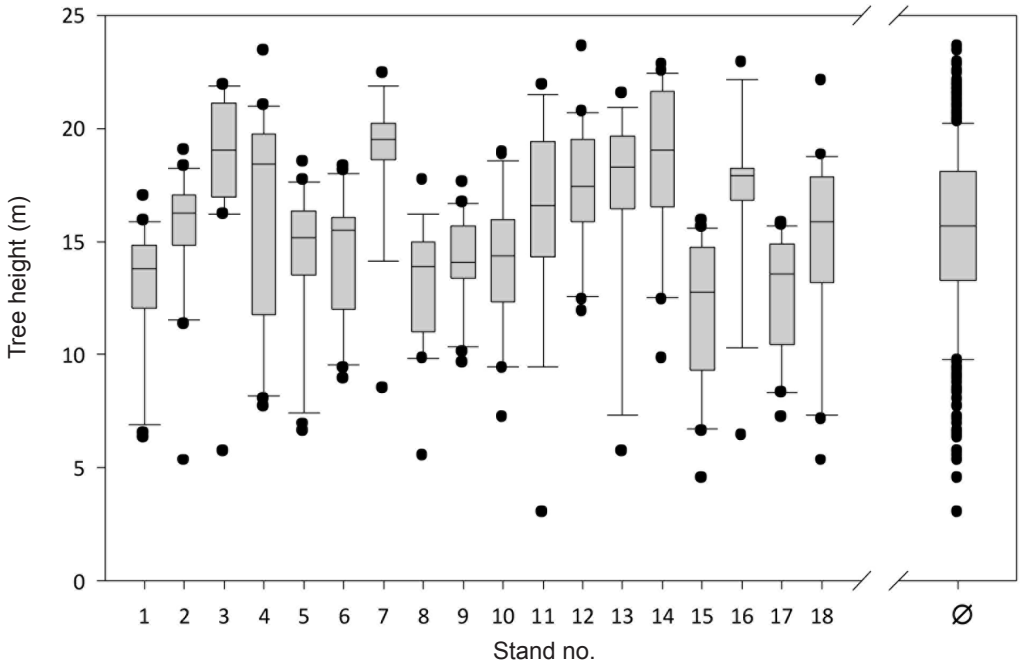

Figure 1 Variability of tree height in 18 smallholder teak stands in SW China; box indicates the 25th and 75th while the whiskers the 10th and 90th percentile; all outliers are included; the continuous line in each box shows the median value; the last box represents all trees inventoried, independently from the stand

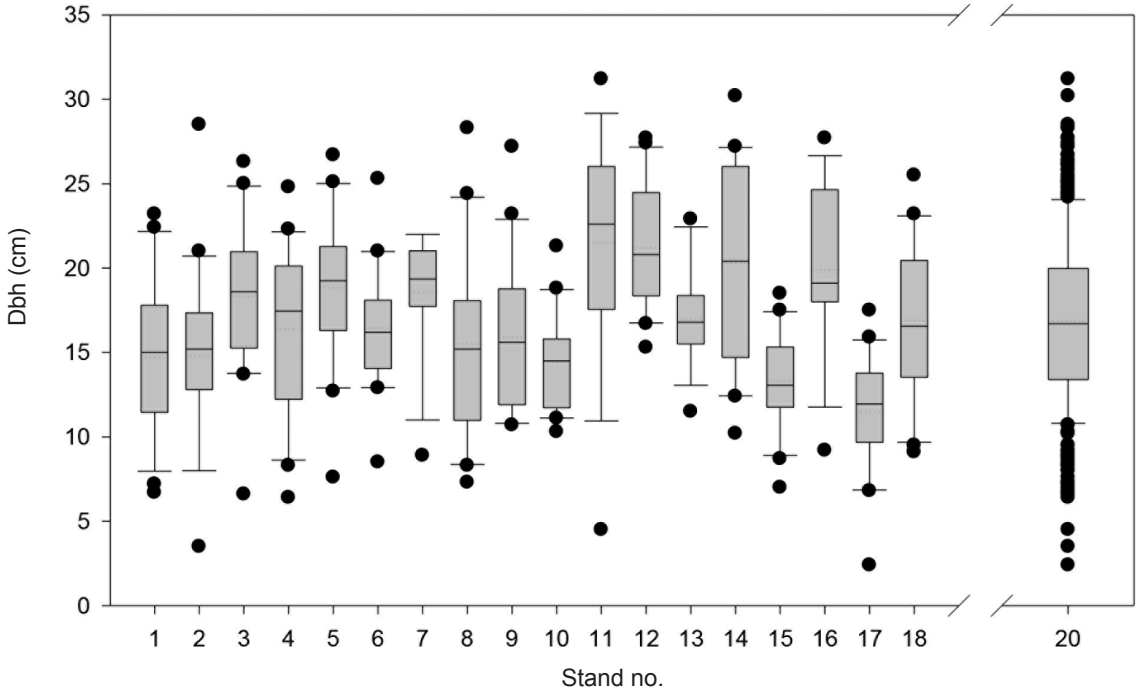

Figure 2 Variability of diameter at breast height (dbh) in 18 smallholder teak stands in SW China; box indicates the 25th and 75th while the whiskers the 10th and 90th percentile; all outliers are included; the continuous line in each box shows the median value; the last box represents all trees inventoried, independently from the stand

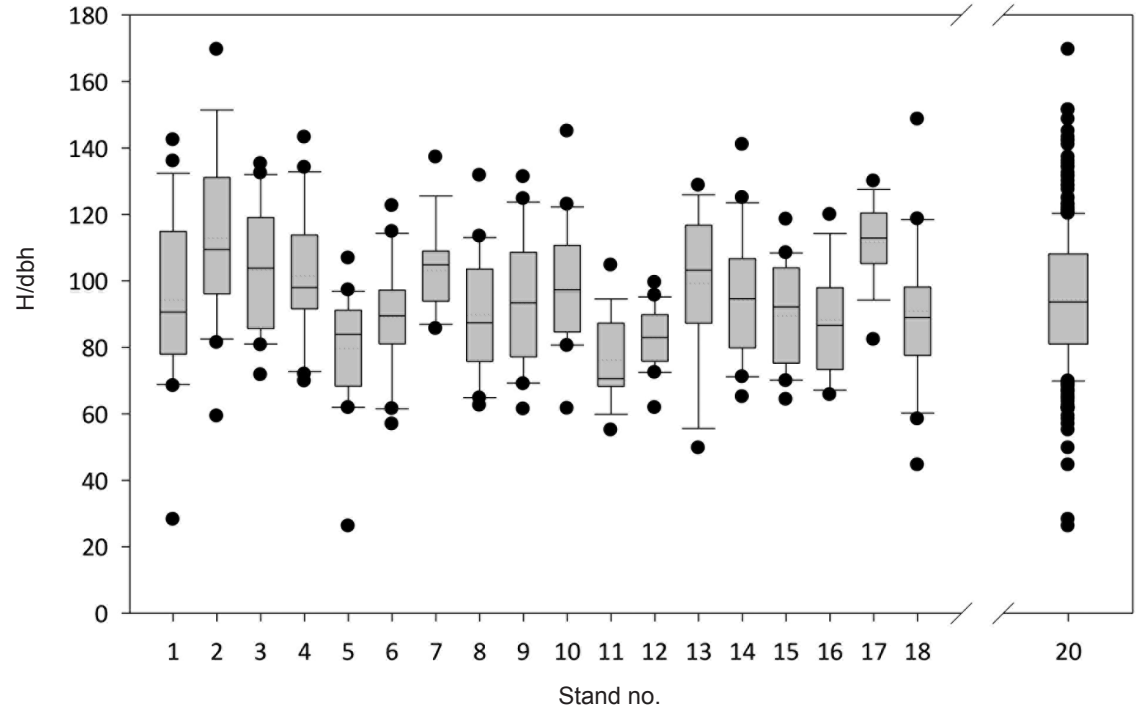

Figure 3 Variability of height over diameter at breast height (h/dbh) values in 18 smallholder teak stands in SW China; box indicates the 25th and 75th while the whiskers the 10th and 90th percentile; all outliers are included; the continuous line in each box shows the median value; the last box represents all trees inventoried, independently from the stand

stands, an average below 100 can be classified as quite good. The highest calculated basal area value in the study area was 44.3 m^2 which was equivalent to 600% of the lowest value (7.4 m^2) (Figure 4). There was high positive correlation between the number of trees and basal area (r = 0.8), as would be expected at this young age. It was noted that the highest figure represented by stand 13 (44.3 m^2) was from a very high density stand (2000 trees ha^{-1}) which also had tall trees (18.3 m). This combination of features could be attributed to the small stand size of only 14 trees and the resulting edge effects. This meant that trees showed characteristics of solitary trees rather than those of trees in plantations where they would be surrounded by other trees and experience competition.

Quality features

All trees which were not forked had straight stems. Nevertheless, nearly 50% of all trees were forked, on average at a height of 6.9 m (42.2% of tree height) (Figures 5 and 6). Self pruning was generally poor and the first branch occurred on average at a height of 2.9 m (18.1% of tree height) (Figure 6). It was reported that an average self-pruning rate of nearly 60% of tree height was considered good for a 17-year-old provenance trial in Tanzania (Madoffe & Maghembe 1988). Thus, the 18.1% documented in this study was low, clearly indicating a lack of silvicultural management in the study area. Although the majority of first branches (92.9%) belonged to class 1 (< 5 cm), 7.9% of trees started with much bigger branches. Given the wide diameter range of class 1 with its high upper limit of 5 cm, the stands can be characterised as being composed of forked and branched trees.

Overall quality was worse when ring swellings and stem damages, which affected 27.8 and 68.8% of the trees respectively, were considered (Figure 5). On average, each tree showed 1.2 ring swellings and 1.5 stem damages. If all quality restrictions were combined, only 12.6% of trees could be classified as flawless. Five of the 18 study stands did not even have one flawless tree (Figure 5).

It was also observed that wounds in damaged stems were mostly associated with termite occurrence. Teak has always been considered as resistant towards termite attacks. However, this study showed that teak was actually vulnerable to such attacks. A similar finding was reported in a study conducted in teak plantations in India (Varma et al. 2007). Other observed damages such as stem swellings which may be the result of stem canker or insects including *Neotermes tectonae* (tree termite) or *Monhammus rusticator* (stem borer), are also common features of plantations (Pramono et al. 2011). Therefore, contrary to claims made especially by teak promoters, teak is in fact not resistant to biotic attacks and its wood suffers from damages.

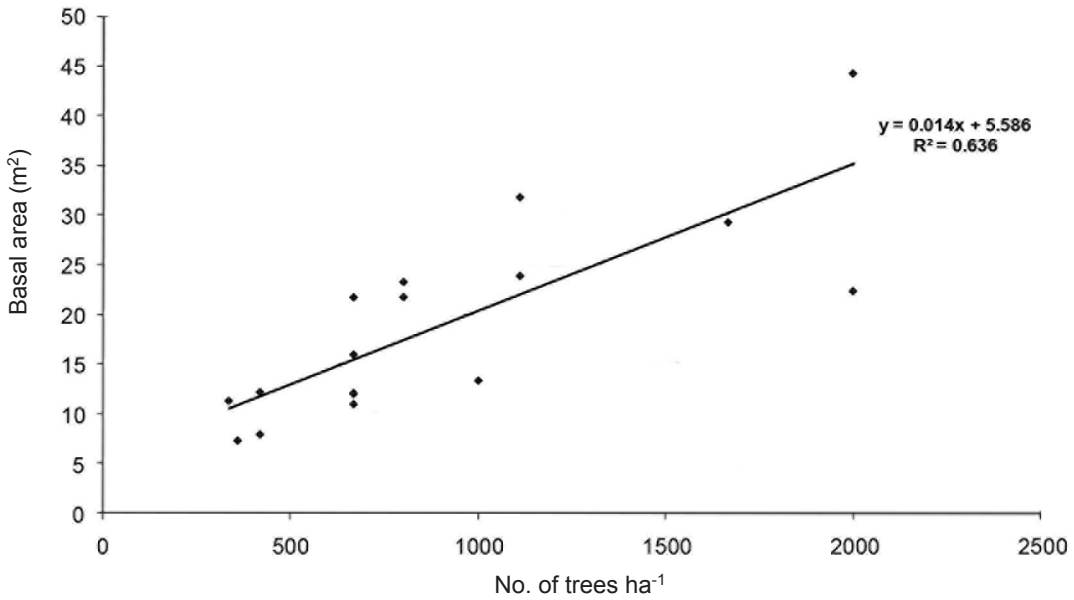

Figure 4 Correlation of basal area and number of trees in 18 smallholder teak stands in SW China

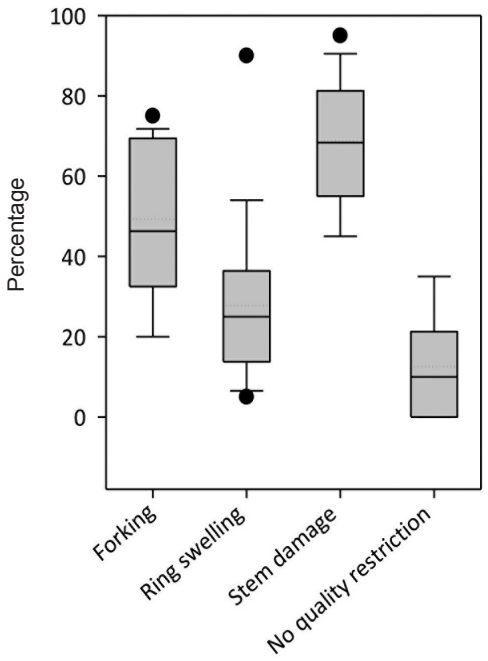

Figure 5 Percentage of trees affected by quality defects in 18 smallholder teak stands in SW China based on median values of each stand; box indicates the 25th and 75th while the whiskers the 10th and 90th percentile; all outliers are included; the continuous line in each box shows the median value; the last box represents all trees inventoried, independently from the stand

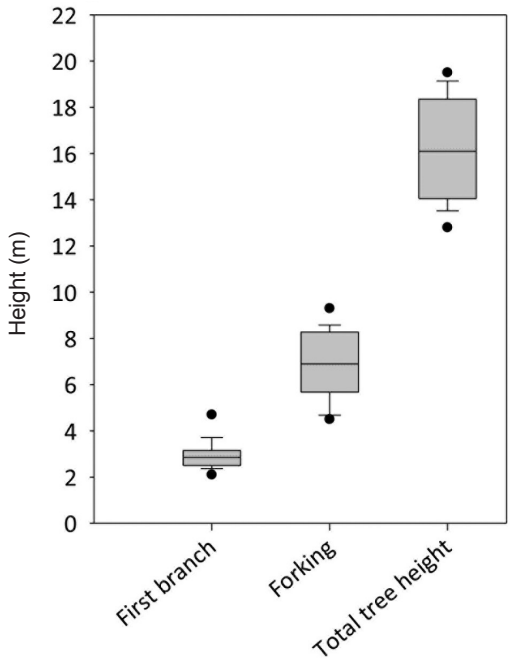

Figure 6 Height of first branch and forking compared with tree height in 18 smallholder teak stands in SW China based on the median values of each stand; box indicates the 25th and 75th while the whiskers the 10th and 90th percentile; all outliers are included; the continuous line in each box shows the median value

DISCUSSION

All study stands showed comparatively high average growth rates. If the stands were thinned to remove weak and ill individuals calculatory growth would be even higher. Even so, the growth performance at this early age is comparable with some well-managed large-scale plantations (Keogh 1982, Krishnapillay 2000). This indicates that the physical environment in the study area is suitable for the growth of the type of teak used. Genetic quality of seed source is well acknowledged in teak (Kjaer et al. 2011). However, we did not study the genotypes of seeds used since the site was poorly managed and no proper records were available.

Moderate tree height to diameter values obtained in the study indicated quite stable trees, given the young age of the stands. Despite high growth rates, all stands experienced high incidence of forking and branching at low heights. Thus, the timber will be of low quality. This problem has also been reported in other studies dealing with smallholder teak (Thulasidas et al. 2006). While the impact of stand management on timber properties and volume development in commercial plantations has been the focus of many studies, the occurrence of stem damages, forking and branching patterns are not scientifically addressed in smallholder plantations. Forked trees seem to be a specific problem in smallholder teak stands (Piotto et al. 2003, Hansen et al. 2005, Mollick et al. 2005). In Indonesia, forking affected more than 50% of smallholder teak (Hansen et al. 2005). This value is comparable with the results of our study. Teak inflorescence is terminal, ending the leading shoot. Therefore, after flowering, two opposite shoots at the base of the inflorescence take over the role of the leading shoot virtually automatically, leading to forking. Thus, age of first flowering determines the occurrence

of forking. However, since flowering is an ecologically complex phenomenon it is very difficult to evaluate the impact of genotype.

Lack of silvicultural management in our research area is understandable considering the extension of natural rubber within the last few years. High price as well as shorter harvesting time is increasingly making rubber the tree of choice among smallholder farmers. Rubber plantations start to provide revenues after five years and this is extremely attractive to farmers who do not have considerable capital stock but need fast returns on their investments.

CONCLUSIONS AND RECOMMENDATIONS

Available data on smallholder teak performance are scarce making it difficult to draw a clear picture of the current regional and global situations. The promotion of teak as a livelihood improvement measure has been popular at the change of the millennium, and many smallholder teak stands should still exist. However, published data based on a scientific analysis is virtually non-existent. Thus, we could not do a good comparison between the current research and other studies. Even grey literature based on teak promotion initiatives by government and non-government organisations is hardly accessible and too often falls into oblivion after completion of projects. It would therefore be desirable if such experience find its way into the scientific community.

It was obvious that in the study area, promotion and introduction of teak as an 'innovation' lacked long-term technical support which was a crucial component for sustainability. Unfortunately, this represents a general flaw of international development cooperation projects and rural-development programmes. The average duration of reforestation and tree planting projects is simply too short. To realise the potential of teak as a long-term investment and at the same time buffering risks of volatile market common in many cash crops including the locally dominating rubber, competent and professional management of teak stands is necessary. This long-term support can only be accomplished by a government institution with mandate beyond project scales providing continual technical or information support. Teak is currently not competitive for investment compared with rubber. However, teak could contribute to the diversification of product portfolio for farmers, be it as boundary planting or even as interspersed trees in rubber plantations.

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