Teak systems' contribution to rural development in Indonesia[1]

James M Roshetko[1], Dede Rohadi[2], Aulia Perdana[3], Gerhard Sabastian[3], Nunung Nuryartono[4], Agus A Pramono [5], Nurin Widyani[5], Philip Manalu[6], Muhammad A Fauzi [7], and Purnomo Sumardamto[8]

1 World Agroforestry Centre (ICRAF) and Winrock International, PO Box 161, Bogor 16001, Jawa Barat, Indonesia, j.roshetko@cgiar.org

2 Forestry Research and Development Agency (FORDA), Jl. Gunung Batu no. 5, Bogor 16610, Jawa Barat, Indonesia

3 World Agroforestry Centre (ICRAF), PO Box 161, Bogor 16001, Jawa Barat, Indonesia

4 International Centre for Applied Finance and Economics, Bogor Agriculture University (IPB), Kampus IPB Baranangsiang, Gedung Utama Lantai Atas, Jl Pajajaran, Bogor 16151, Jawa Barat, Indonesia

5 Balai Penelitian Teknologi Perbenihan Tanaman Hutan, PO Box 105, Bogor 16001, Jawa Barat, Indonesia

6 Centre for International Forestry Research (CIFOR), Jl CIFOR, Situ Gede, Sindang Barang, Bogor 16115, Jawa Barat, Indonesia

7 Centre for Forest Biotechnology and Tree Improvement, Jl Palagan Tentara Pelajar Km 15, Pelem, Purwobinangun, Pakem 55582 Sleman, Yogyakarta, DIY, Indonesia

8 Dinas Kehutanan dan Perkebunan Kabupaten Gunungkidul, Jl Brigjen Katamso no. 8, Wonosari, Gunungkidul, DIY, Indonesia

Keywords: silviculture, smallholder farmers, timber production and marketing, intercropping, tumpangsari

Abstract

Teak is a valuable tropical timber species produced in industrial plantations in more than 43 countries. National and international demand for teak timber exceeds the sustainable yield from plantations. High demand creates opportunities for enterprising farmers. Teak is now grown in smallholder systems in many tropical countries, as one component of integrated multispecies' agroforestry systems. These systems enable farmers to diversify production, reduce farm risk, contribute to food security, and generate much needed income. This paper reports the contributions of smallholder teak systems to rural development in Indonesia, where farmers have been producing teak for over 50 years. Indonesian farmers cultivate various mixed tree and annual crop systems, with teak accounting for 56% of the tree component. Annual cropping is an important aspect of these systems, producing commodities for both household consumption and market sale. Besides supplying food for households, smallholder teak systems provide 40% of household income from agricultural and timber crops. Teak and other tree crops allow households to re-allocate labor to off-farm employment when those opportunities are lucrative. However, farmers suffer from limited resources, labor and access to information, which constrain the productivity of their teak systems. Specific recommendations are provided regarding how smallholders can adopt improved silvicultural and marketing management. Roles for government, support agencies and industry are outlined that would provide benefits to all parties. Policy changes are identified that would motivate smallholders to improve the

[1] Paper presented at the World Teak Conference 2013, Bangkok, Thailand, 24–27 March 2013

management of their teak systems. Conclusions and recommendations are applicable to smallholder teak systems across the tropics.

Introduction

Teak (*Tectona grandis*) is arguably the best-known, most valuable and widely produced tropical hardwood species. Its timber is durable, strong, easy to work and commonly used to produce furniture, housing materials, crafts, ships and many other products. The species occurs naturally in India, Myanmar, Laos and Thailand. There are approximately 23 million ha of natural teak forest, with almost half occurring in Myanmar (Kollert and Cherubini 2012). Teak is naturalized in Indonesia, where it was introduced from India as early as the second century (Simatupang 2000). The demand for teak timber has been high for centuries. On Java, plantations to support ship building are believed to have been established during the 13th century (Simatupang 2000). In Sri Lanka, plantations were first established in 1680. Teak planting started in India in the 1840s and increased greatly after 1865. Teak plantations were established using the *taungya* intercropping system in Myanmar in 1856, with the system spreading to Indonesia around 1880 (Pandey and Brown 2000). Wiersum (1982) reported the taungya system was employed to establish teak on Java in 1856. Thailand developed plantations in 1906 (Krishnapillay 2000).

Teak plantations were established in Africa and tropical America in the early decades of the twentieth century; 1902 in Nigeria, 1905 in Ghana, 1913 in Trinidad and Tobago, and 1927–1929 in Honduras, Panama and Costa Rica (Pandey and Brown 2000). Teak plantations now exist in at least 43 countries. The global area of teak plantations is a minimum of 4.3 million ha, of which 83% is in Asia, with India, Indonesia, and Myanmar having the largest areas. Plantation ownership is dominated by governments in Asia, Africa and the Caribbean and by corporations in Central and South America. Smallholder plantings are a small but important contribution, comprising 19% of the area in Africa and Asia, and 31% and 34%, respectively, in Central and South America (Kollert and Cherubini 2012).

The early demand for teak timber exceeded the sustainable supply from natural forests, leading to the development of commercial teak plantations in the late 1800s in South and Southeast Asia. Similarly, contemporary demand at the international and national levels generally exceeds the sustainable production from plantations, and a limited sustainable harvest from natural forests in Myanmar. India, Laos and Thailand all maintain logging bans in natural teak forests. The increasing difference between the demand and supply of teak creates opportunities for smallholder production. Conditions in Indonesia, the second largest producer of teak (behind India), may be representative of other teak-growing countries. The center of the Indonesian teak industry is Central Java, where the industrial demand for teak timber is 1.5 to 2.2 million m^3 per year (Roda *et al*. 2007). Perum Perhutani, the state-owned forest enterprise that is the largest manager of teak plantations, at 2.4 million ha, produced 477,000 m^3 of teak in 2008, most of which was sold to the commercial teak industry (Perhutani 2010). According to Ewasechko (2005), the shortfall in supply is sourced from smallholder/community producers, other teak-growing regions, imports from overseas, and illegal harvests from Perhutani plantations.

There are approximately 1.5 million smallholder farmers on Java managing 444,000 ha of tree-based agroforestry systems, where teak is the dominant tree crop. In other parts of Indonesia

there is an additional 800,000 ha of smallholder agroforestry where teak is one component of multispecies, tree-based systems (Nawir *et al*. 2007). Smallholder teak plantations became common on Java in the 1960s. By the 1980s, teak production was seen as an attractive alternative source of livelihoods. The national government's rehabilitation and regreening program supported and strengthened farmers' interest in developing tree-farming systems (Rohadi *et al*. 2011). Over time, smallholder teak production has become an important source of raw material for the Javanese furniture industry and income for rural families (Roshetko *et al*. 2012).

Smallholder teak production has emerged as important in other countries and regions as well. In northern Laos, teak is a key component of integrated smallholder farming systems that reduce risk and diversify farm production. Teak-based systems enable farmers to transform swidden land to tree cover, reducing labor needs that can then be allocated to other household or off-farm opportunities. High market demand and expanding infrastructure makes teak production a positive contribution to household economies (Midgley *et al.* 2007; Newbury *et al.* 2012). In Thailand, teak is considered suitable for smallholders because of its high value, high demand, and ease of cultivation which fit local farming systems to diversify production and income. However, farmers needed assistance to adopt teak because of their pressing need for short-term economic return and limited access to land (Mittelman 2000).

Smallholder farmers in Togo grow teak on their farms to increase household income, even though it competes with the production of staple crops such as maize and cassava. Agricultural land and labor are scarce and food security is important. Yet farmers are willing to plant teak to improve family assets. Under local conditions, 15-year rotations provide the best returns for poor farmers (Kenny 2007). For similar reasons, smallholder farmers in southern Benin grow teak on short rotation to produce poles of 5 to 15 cm (Aoudji *et al.* 2011). In Nigeria, teak enables farmers to participate in national afforestation activities and contribute to national environmental goals. Growing teak extends fallow periods, rehabilitates soil fertility, diversifies farm production and increases household income (Osemeobo 1989). As in other countries of the humid tropics, biophysical and market conditions in Panama create opportunities for smallholder teak production. However, for those systems to achieve their potential, farmers need access to land, technical information, market knowledge, and quality germplasm (Zanin 2005). Similar observations and recommendations have been made for smallholder teak in Costa Rica (De Vriend 1998).

While timber is the most common and important teak product for smallholders, a number of other uses also contribute to rural livelihoods. Oil extract from teak leaves and wood is used as a traditional medicine to treat skin diseases in India (Gupta *et al.* 2010, Siddiqui *et al.* 1989, Gupta *et al.* 1997). Teak leaves are made into a compress to hasten healing of skin wounds (Majumdar 2005). Dyes from the leaves and buds are used as henna (Sharma 1999) and to dye cloth (Bhuyan *et al.* 2004, Widiawati 2009). Dried teak leaves can be used at low concentrations (no more than 5–25%) as a dry season feed supplement for goats and sheep (Anabarasu *et al.* 2001, 2004, Reddy and Reddy 1984). Dried leaves are also used as roof thatching in Bangladesh (Chakraborty and Bhattacharjee 2003). Sawdust of teak is used in Indonesia to make incense (Roemantyo 1990). Bark, leaves, wood pulp, and sawdust all have industrial uses; smallholders benefit from those uses by providing raw material to local industry. On Java, *Hyblaeca puera*, a caterpillar commonly found on teak, is collected to cook as a side dish or sell (Pramono *et al*. 2011).

This paper summarizes the contributions of smallholder teak systems to rural livelihoods in Indonesia. Emphasis is placed on research conducted in Gunungkidul, Yogyakarta in central Java. Information from other parts of Indonesia and other countries are included when relevant.

Methods and material

Research site

A research project on smallholder teak agroforestry systems was conducted by the Center for International Agroforestry Research (CIFOR), the World Agroforestry Centre, the Indonesian government's Forestry Research and Development Agency (FORDA) and other local partners from 2007 to 2010 with the support of the Australian Centre for International Agricultural Research (ACIAR Project FST/2005/177). The project site was Gunungkidul, one of five districts in Yogyakarta Province (Special Region), located in central Java at 7º46'–8º 09' latitude and 110º 21'–110º 50' longitude (Figure1). Gunungkidul was selected as the research site because it has a long history of successful smallholder teak production.

The Gunungkidul landscape is characterized by hilly terrain, with half the district having slopes of 15% or more. The northern zone of the district is hilly with elevations from 200 to 700 meters above sea level (masl); the central zone is primarily flat with some hills with elevations of 150 to 200 masl; the southern zone is characterized by infertile, dry karst (limestone) soils at elevations of 100 to 300 masl. Average annual rainfall is 1500 to 2500 mm. The population of the district is approximately 685,000, with an average family size of four. Agriculture is the main component of the district's economy, providing 34% of gross income and the most employment. Within the agricultural sector, food crops account for 64.0% of economic value, followed by forestry (27.3%), livestock (6.3%), plantation crops (1.7%), and fisheries (0.7%). In 2007, gross per capita annual income was IDR 7,110,408, approximately UD 750 (Rohadi *et al.* 2011).

Research methods

Village selection was conducted collaboratively between the project team, local government agencies and communities. The aim was to select communities that were representative of the district's three zones: the northern zone (Baturagung Mountain Range), the central zone (Ledok Wonosari area) and the southern zone (Gunung Seribu Mountain Range). The following villages were selected as key sites: Katongan (Nglipar sub-district) and Candirejo (Semin sub-district) in the northern zone; Bejiharjo (Karangmojo sub-district) and Karangduwet (Paliyan sub-district) in the middle zone; and Dadapayu (Semanu sub-district), Giripurwo (Purwosari sub-district) and Giripanggung (Tepus sub-district) in the southern zone.

A baseline study of 275 teak-farming families, managing 1074 land parcels on a total of 276.5 ha, was implemented to identify the socioeconomic conditions and farming characteristics of smallholder systems. An inventory of 227 teak farms covering 47.1 ha and a farm management survey of 275 farmers were conducted to document the composition and management practices of smallholder teak systems. A rapid market appraisal of 295 respondents (277 farmers, 11 traders, and 7 sawmill owners) was conducted to identify smallholders' teak-marketing practices and related opportunities. Farmer demonstration trials (Roshetko *et al.* 2005) were designed and established collaboratively with landowners on six farms to show the advantages of silvicultural management under smallholder conditions. Additionally, interviews with key respondents and focus group discussions were conducted to triangulate information, fill

information gaps, and gain a comprehensive understanding of key issues. The results from some of these studies have been published and are cited here.

Results

Socioeconomic and cultural characteristics of teak

The average landholding per family was approximately 1 ha, varying from 0.5 to 3.0 ha, and consisted of multiple parcels. Thirty-seven percent (37%) of smallholder teak growers cultivated less than 0.5 ha, 26% cultivated 0.5 to 1 ha, 25% cultivated 1 to 2 ha, and only 12% cultivated more than 2 ha. Ten percent (10%) of farmers' land was dedicated to teak woodlots, called *kitren*. Farmers also cultivated teak and other tree species in annual cropping systems and homegardens. More details regarding teak systems are provided below in the 'Smallholder teak systems' subsection.

Annual household income varied greatly, from zero to IDR 58 million, with an average of IDR 10 million (USD1125). Most household income (61%) was derived from off-farm sources, including casual and skilled labor, shopkeeping, home industries, and services; 25% from annual cropping and livestock systems; 12% from teak; and 3% from other timber species. Common agricultural crops were rice (*Oryza sativa*), cassava (*Manihot utilissima*), peanuts (*Arachis hypogaea*), soy beans (*Glycine max*), corn (*Zea mays*), bananas (*Musa* spp) and other vegetables (Rohadi *et al.* 2011).

In Gunungkidul, teak was considered a valuable asset and important part of the local culture. Over half of farmers (54%) reported the main reason for planting teak was for family savings; 23% planted teak primarily because it was part of their cultural heritage; only 15% of farmers planted teak in response to maximizing market opportunities; 9% of farmers established teak based on the influence or success of neighbors (Rohadi *et al.* 2011).

Teak trees served as a living savings account. Trees were harvested when significant cash needs arose, such as weddings, school fees, large medical expenses, periodic social commitments or emergencies. Generally, farm families refrained from selling their teak trees until other disposable assets, such as motorcycles, electronic goods, jewelry or livestock, had been sold (Perdana *et al.* 2012). The practice of selling teak to meet financial needs was called *tebang butuh* ('felling for needs').

To cover common daily expenses (food, medical, etc), when household cash was not available, farmers preferred to take loans rather than harvest teak. Most loans (78%) were sourced from the informal sector, mainly family and local rotating savings groups; 22% of loans came from the formal sector, primarily banks. Only 12% of farmers took loans to support agricultural intensification or strategic agricultural investment, the purchase of agricultural inputs (seeds and chemicals) or equipment. Farmers did not take loans to plant teak. The private and government banking sectors were both reluctant to provide loans for smallholder timber system establishment (Rohadi *et al.* 2011).

Smallholder teak systems

There were four smallholder teak production systems: kitren, *tegalan*, *pekarangan* (homegardens), and line plantings. Kitren are woodlots dominated by teak. Tegalan are upland systems where trees and annual crops are intercropped. Pekarangan are dominated by tree

species, with annual crops commonly cultivated in the understory. Border planting can be around or across irrigated rice land or other annual cropping systems. Kitren and tegalan are commonly found 1.0 to 1.5 km from the owner's house. Pekarangan are located adjacent to the owner's house.

Tegalan were the most common and larger of the teak systems, accounting for 50.6% of smallholder teak system parcels, averaging 0.47 ha. Kitren accounted for 21.9% of the parcels, averaging 0.31 ha. Pekarangan also accounted for 21.9% of the parcels, averaging 0.24 ha. Irrigated rice (*sawah*) accounted for less than 5% of farmers' parcels. Kitren had the highest tree density and the least species diversity (Table 1). Across all systems, teak accounted for 55.9% of the trees (Figure 2) and 47.2% of the regeneration (Roshetko and Manurung 2009). Overall, timber species (including teak) accounted for 77.0% of trees; fodder species 15.0%; spice, nut and condiment species 3.4%; and fruit 2.2%.

Eighty-two percent (82%) of farmers reported intercropping their teak systems with agricultural crops. In the year of the survey, 44% of teak systems were intercropped, including 54.4% of tegalan, 34.4% of pekarangan, and 11.2% of kitren. The most common intercrops were cassava (26.6% of intercropped parcels), peanuts (23.8%), upland rice (18.0%), soybeans (8.1%), and long bean (*Vigna unguiculata* subsp *sesquipedalis*, 2.9%).

Silvicultural management

Traditional smallholder tree management is not intensive or proactive. Smallholders rarely used quality germplasm: 72% of farmers established teak systems with wildings, 30% used local seedlings, and 20% used coppice. Only 12% of farmers had ever used improved quality seedlings, primarily material provided free through government reforestation programs. Weed control and fertilizer application was practiced by 73% of farmers, but only in association with annual crop production. Pruning was practiced by 64% of farmers to harvest fuelwood; overall, 55% of smallholder teak trees had been pruned. Unfortunately, pruned trees usually retained branch stubs of 10–15 cm, which generally reduced timber quality. Overall, 43% of teak systems in Gunungkidul had been thinned, but with the primary objective to harvest timber, poles, or fuelwood. Commonly, farmers' thinning operations removed the best quality trees. Although coppice was commonly used in teak systems, coppice thinning was not practiced (Roshetko and Manurung 2009).

Silvicultural trials

Four thinning and pruning demonstration trials were established in kitren systems. Two coppice-thinning demonstration trials were established in tegalan systems. All systems were even-aged with trees and coppice approximately 4–6 years-old. The silvicultural practices and treatments investigated were: thinning (control and 40% thinning); pruning (control, pruning to 50% of total height, and pruning to 60% of total height); and coppice thinning (control and singling). Relevant information regarding the trials is summarized in Table 3. Thinning of 40% was selected to obtain a residual stand density of approximately 625 trees/ha (4 x 4 m spacing). The effect of silvicultural treatments was greatest during the rainy season (September 2008 to May 2009 and November 2009 to May 2010). Average annual increment over the 2-year period showed that the combined 'thinning and 60% pruning' treatment increased diameter at breast height (dbh) by 60% and tree height by 124% compared to the' no pruning and no thinning' control (Figure 3). The singling treatment demonstrated the benefit of managing teak coppice by thinning to the single healthiest stem, with the singling treatment demonstrating 45% greater incremental growth

during the rainy seasons (Figure 4). Results of the 2-year trials demonstrated that proper thinning, pruning and singling improved the dbh and height growth of smallholder-grown teak trees.

Investment and marketing system

The costs and time required to establish teak systems was not a deterrent to smallholders. The cash costs to farmers were low. The initial investment in germplasm was made through the national rehabilitation and regreening program in the 1980s. As detailed above, most farmers used local germplasm (wildlings, seedlings or coppice) to establish or reestablish their teak planting. A limited number of farmers received donations of improved quality seedlings. Management costs for fertilizers and weeding were associated with annual crop production. Planting and other tree management activities were conducted when opportunity costs were low for other on-farm or off-farm activities.

Key actors involved in the smallholder teak timber marketing chain were farmer producers, local traders, large-scale traders (wholesalers), and processors. The farmers' role was limited to producer. They engaged the marketing chain through local or large-scale traders, but generally had limited access to market information. Standing trees were the standard unit of sale for farm-grown teak. Traders were responsible for tree harvest and transport. Traders visited the farm to measure and assess the tree and negotiate the price for individuals or blocks of trees. Negotiation was done without clear quality or value standards.

To obtain a better price, 51% of farmers collected information from other farmers who had recently sold trees. Thirty-one percent (31%) of farmers improved their negotiating position by offering the same trees to two or more buyers. The remaining farmers (18%) acted as price takers. Regardless of the negotiation approach taken, farmers usually obtained prices that were well below market rates because of their limited access to market information, weak negotiating position and inability to minimize the market transaction costs, including transportation. Traders also faced challenges. They conducted transactions with numerous farmers, each producing small quantities of small diameter trees. Timber quality was variable. Some trees had severe defects, such as hollow stems, which were difficult to detect until harvesting. This condition resulted in high transaction costs, leading to lower prices for farmer-producers. The market reflected higher prices for older, larger trees (Table 2). However, only 14% of farmers harvested trees based on economic maturity; most (80%) followed the tebang butuh practice (Perdana *et al.* 2012).

Discussion

In Gunungkidul, smallholders cultivated teak in four systems: kitren, tegalan, pekarangan, and as line plantings. Teak was the main tree component of these systems, accounting for 56% of all trees. Other timber species comprised an additional 21% of the tree component. Kitren are woodlots primarily dedicated to producing teak timber for market sales, but are also utilized for annual crop production. Tegalan and pekarangan are mixed production systems, intended to produce both tree and annual crops. Annually, over half of tegalan and one-third of pekarangan were intercropped. Eighty-two percent (82%) of farmers managed their teak production systems for both short-term annual crop production and medium-to-long-term timber production. Besides the food produced for household consumption, these systems provided 40% of overall household income (25% from agricultural production, 12% from teak, and 3% from other timber).

The traditional practice of intercropping is called *tumpangsari*. It is important to contrast this practice with the previously mention taungya system. Taungya is a plantation establishment method where tree seedlings are intercropped with annual crops to improve tree establishment and early growth. The costs of plantation establishment can be offset by agricultural production. In taungya, intercropping is limited to the first 1–3 years. Tumpangsari is a farming strategy to diversify farm production, reduce farm risk, produce food and increase farm income. With tumpangsari, intercropping is not limited to the tree establishment phase but is practiced with trees of all ages. Because of competition for light, nutrients and moisture, systems with lower tree density are more favorable to intercropping. Hence, tegalan and pekarangan systems are more frequently intercropped than kitren systems.

In Gunungkidul, decisions regarding when and what to intercrop were based on prevailing market prices for agricultural crops, available household labor, and household capital. Only a limited number of farmers (12%) borrowed money to support annual crop production with the intention of paying back the loan with profits from crop sales. Intercropping costs were justified by anticipated yields from annual crops. The positive impacts of intercropping on tree growth were a welcome benefit, but were not considered in decisions to cultivate annual crops. If costs were judged to be too high, farmers pursued off-farm opportunities where returns to labor were perceived to be higher. Proximity to urban employment opportunities in Central and East Java facilitate temporary migration to those areas and the extensification of tree farming (particularly timber) as living savings accounts. Under these conditions, tree farming is seen not only as a means to diversify farm production, reduce risk, and build family assets, but also as an effective way of reallocating labor to lucrative off-farm employment opportunities (Roshetko *et al.* 2008a).

Timber is not the only teak product that generated income for smallholders. Collecting and producing teak germplasm is also profitable. Farmers in Wonogiri, Central Java, and Ponogoro, East Java, earn IDR 28,000–35,000 a day (USD 3.30–4.10) supplying teak seed to seed dealers and companies. Farmer seed collectors estimate they earn IDR 275,000–795,000 (USD 32–94) a year by collecting and processing tree seeds of all species, which equaled 33–66% of household cash incomes during the 3-month tree seed season. Teak accounts for 20% of the overall tree seed collected and sold. Approximately 22,500 farmers are involved in the tree seed sector (Roshetko *et al.* 2008b). In Lampung, Indonesia, 24% of farmer nurseries and 100% of farmer timber tree nurseries produce teak trees for sale to government, commercial, and farmer customers (Purnomosidhi *et al.* 2012). Working in Costa Rica, Cornelius *et al.* (2010) found that smallholders can earn significant income by supplying germplasm of teak and other priority species to tree-planting projects or organizations.

Analyzing smallholder timber production systems in Yogyakarta and South Kalimantan, Rohadi *et al.* (2010) determined that intercropped systems where more viable than monocultural systems. Key to the success of these systems were market access, food crop production (food security), and diversified production to provide short-term and long-term returns. Van Der Poel and Van Dijk (1987), Filius (1997), and Nibbering (1999) have all commented on the importance of market access to the successful establishment of tree-farming systems in Central Java and Yogyakarta. The development of teak systems in Gunungkidul fits the hypothesis that smallholders adopt agroforestry systems that diversify production, reduce farm risk, provide food security and yield economic returns. In adopting such systems, smallholders seek to optimize the use of land, trees, household labor, and capital, while minimizing constraints (Scherr 1995).

Besides enhancing rural livelihoods, the development of smallholder agroforestry systems has had a huge impact on environmental conditions and the supply of timber to the local industry. In the 1950s, severe poverty and land degradation were widespread in Central Java and Yogyakarta. Many areas were nearly treeless, soil erosion was critical and agricultural production failing. A number of drought-induced famines occurred (Van Der Poel and Van Dijk 1987, Nibbering 1999). Smallholder agroforestation[2] helped communities rehabilitate their farms, reverse soil erosion, diversify production and improve food security (Van Der Poel and Van Dijk 1987, Soerianegara and Mansuri 1994, Filius 1997, Nibbering 1999). Smallholder teak systems in Laos (Midgley *et al.* 2007) and Nigeria (Osemeobo 1989) have improved fallows, rehabilitated soils and facilitated a return to tree cover. From a nearly treeless state in the 1950s, Gunungkidul now has tree cover of 28.1% (41,773 ha). State forest land accounts for 8.9% of the total and smallholder agroforestry systems 19.2% (Badan Pusat Statistik Kabupaten Gunungkidul 2008). As the industrial demand for teak timber continues to increase, the supply of timber from Perhutani plantations has declined. In response, smallholder teak farmers have increased production and become an important source of raw material for the furniture industry in Java (Roshetko et al. 2012).

Despite smallholders' existing role and potential to supply the timber industry, there are significant impediments to profitable smallholder teak plantations. Key among those are poor silvicultural management and limited market awareness. The stocking of smallholder teak systems in Gunungkidul was very dense, 2.5 x 2.5–3 x 3 m (Table 1). Those are appropriate planting densities for teak plantations, but thinning should follow five-year cycles to reduce densities as trees grow (Pramono *et al.* 2011). Effective thinning was uncommon in smallholder systems. Smallholders did not thin to improve the growth or quality of the remaining trees. As practiced by smallholders, thinning usually removed the biggest or better quality trees before the trees reached economic maturity. Similarly, pruning was not conducted to improve tree quality, but to harvest fuelwood. Farmers usually left 10–15 cm branch stubs, which reduced timber quality if not removed. When planting teak, most smallholders used wildings or other local germplasm because improved planting material was expensive and not readily accessible. No farmers weeded or fertilized their teak systems, in the absence of annual crops. Smallholders' standard management practices limited the productivity of their systems, resulting in smallholder teak systems being characterized as overstocked, slow growing and of sub-optimal quality and production (Roshetko and Manurung 2009).

Working at other locations in Central Java, Kallio *et al.* (2012) also found that silvicultural practices limited the performance and quality of smallholder teak plantings. Poor silvicultural practices by smallholder teak farmers have been reported in several other countries: by Midgley *et al.* (2007) in Laos, Mittelman (2000) in Thailand, De Vriendi (1998) and Zanin (2005) in Panama, and for smallholder systems in general by Bhat and Ma (2004). Additionally, and similar to Gunungkidul, farmers in Laos (Midgley *et al.* 2007), Panama (Zanin 2005) and Togo (Kenny 2007) primarily use local germplasm (wildlings or seed) of unknown or dubious quality to establish their teak systems.

Sabastian *et al.* (2012) found that access to larger areas of land and greater on-farm income made farmers more likely to adopt silvicultural management compared to other farmers. Kallio *et al.* (2011) also found that in Java, Riau and South Kalimantan, smallholders' socioeconomic

[2] Agroforestation refers to the establishment of smallholder agroforestry systems, and implies land rehabilitation through the establishment of a tree-based system and intensification of land management (Roshetko *et al.* 2007).

conditions influenced their timber management practices. However, at other sites in Central Java, Kallio *et al.* (2012) found that the socioeconomic conditions did not affect teak farmers' tendency to adopt silvicultural management.

In Gunungkidul, the lack of awareness regarding the positive influence of proper silvicultural management prompted farmers' indifference to the adopting the practices. Kallio *et al.* (2012) also reported that farmers' poor understanding of what constituted good quality teak trees might limit management. To build farmers' understanding, silvicultural trials were designed and implemented by the project team and farmer-landowners. The trials demonstrated that silvicultural management was effective under smallholder conditions. Over a 2-year period, the thinning and pruning treatment increased incremental diameter breast height (dbh) by 60% and incremental tree height by 124% (Figure 3). The singling treatment increased incremental dbh by 45% compared to control treatments (Figure 4). Additionally, the project team in collaboration with farmers and forestry extension officers developed a farmers' teak silvicultural manual (Pramono *et al.* 2011). The trials and the manual were used in training activities and successfully built the capacity of smallholder farmers. An assessment conducted by university students found that 70% of the farmers in the project area increased their knowledge of silvicultural practices, with 50% adopting silvicultural practices on their own farms and 30% disseminating management practices to other farmers. In areas neighboring the project, 30% of farmers increased their silvicultural knowledge as a result of project activities, with 20% adopting silvicultural practices and 15% sharing information with others (Rohadi *et al.* 2011).

This experience corresponds with that of other authors who have commented on the need for capacity building and trials to strengthen smallholder silvicultural practices. Midgley *et al.* (2007) recommended field demonstrations to show smallholders the benefits of silvicultural (thinning and pruning) management. Newby *et al.* (2012), Zanin (2005), Bhat and Om (2000) and De Vriendi (1998) all called for more capacity building and technical support to facilitate the adoption of silvicultural management by smallholder teak farmers.

Other issues also affected smallholder decisions regarding teak management. Smallholders have limited capital and household labor. They allocate those resources to generate the best returns. Teak is not prioritized, nor do smallholders take loans to finance teak establishment or management. Farmers' minimal investment in teak management reflects limited market incentive and the long-term nature of the crops. Limited investment is reasonable, as teak and other timbers are not the main household income. Perdana *et al.* (2012) stated that investment in smallholder teak systems was only marginally profitable, which was partially due to limited market incentives and restrictive government policies. It is also possible to argue that farmers' opportunistic management of teak, when other on-farm or off-farm alternatives are less attractive, provides good returns on their limited investment. Their approach to teak management enables smallholders to minimize risk, diversify production, effectively use household resources, and grow a living saving accounts to meet significant cash needs under their tebang butuh strategy.

Both farmers and traders are motivated by higher prices for higher quality timber. However, farmers' incentives to produce higher quality timber are constrained by poor market links. Those links are restricted by limited access to market information, a weak negotiating position, and the production of small quantities of undersized trees of uncertain quality. Perdana *et al.* (2012) suggested improving market information by introducing smallholders to the log grading and pricing systems used by the timber industry. Training sessions lead by industry experts could

improve the knowledge of smallholders as well as local traders to whom they sell their logs. These interactions could be further expanded to become farmer-industry partnerships where farmers produced trees to meet market specifications. The development of a valuation system for on-farm standing trees could reduce the risk for both smallholders and traders. Improving their confidence in the price to be received could provide the incentive smallholders needed to produce better quality timber.

Traders justify paying low prices for farm-grown teak because of the time required to identify individual farmers who want to sell their trees and that each farmer sells small quantities of small diameter logs. This process results in high transaction costs, which benefits neither smallholders nor traders. The development of group marketing systems to coordinate the sale of large quantities of logs per transaction would create economies of scale and enhance the negotiating power of groups of farmers (Holding-Anyonge and Roshetko 2003, Midgley *et al.* 2007). The farmer marketing group could also institute a diameter limit that would assure each tree sold yielded higher volumes of merchantable quality timber (Perdana *et al.* 2012). The efficiencies of dealing with groups of farmers and purchasing large volumes of better quality timber would enable traders to pay higher prices. This is a potential win-win situation to improve the inefficiencies of existing smallholder teak marketing systems.

The adoption of more intensive silvicultural practices would produce larger, higher quality timber. To maximize the production of merchantable teak timber, Kanninen *et al.* (2004) recommended heavy early thinning of plantations in Costa Rica, specifically 60% thinning at the age of 4 years or two consecutive 25% thinnings at 4 and 5 years. Based on initial findings from the local trials, a similar prescription would be appropriate for smallholders in Yogyakarta. An obstacle to early heavy thinning remained farmers' reluctance to cut trees that could not be sold. Most farmers viewed thinning as a loss of future income rather than improving the quality and value of the remnant stand. One option to make early heavy thinning more acceptable is to establish teak in mixed plantations with short-rotation species such as *Gmelina arborea* or *Paraserianthes falcataria* (Roshetko *et al.* 2004). Harvesting the short-rotation species after 5 years would constitute an early heavy thinning with economic return. Selection of short-rotation species should be based on local market demand. Through computer simulation, Sebastian (2012) found that net present value and return to labor for smallholder teak systems is higher if farmers practice silviculture compared to no tree management. Improved benefits were generated from both agriculture and timber crops.

Another major obstacle to profitable smallholder teak production in Indonesia is policy disincentives. Simplifying timber trade regulations regarding smallholder teak would minimize transaction costs, improving market efficiencies. Perdana *et al.* (2012) recommended including smallholder teak in the certificate-of-origin scheme (*Surat Keterangan Asal Usul*), which validates the transport, possession or ownership of timber from the forest or community land rights; or excluding smallholder teak from requiring a certificate of legal logs (*Surat Keterangan Sahnya Kayu Bulat*) or a certificate of legal forest product (*Surat Keterangan Sahnya Hasil Hutan*), which are intended to regulate timber production in natural forests and control illegal logging. Simpler, more relevant regulations for the smallholder timber trade would provide smallholders with incentives to invest in teak silviculture. Additionally, project results found that the development of affordable micro-credit programs to help farmers cover short-term and unexpected expenses could enable those farmers to refrain from harvesting undersized teak trees

of low market value, retaining them until they reached merchantable size and lucrative value (Rohadi *et al.* 2011).

Conclusion and recommendations

Smallholder teak systems in Gunungkidul are a low-input alternative strategy for rural development and enhancement of livelihoods. The systems diversify farm production, reduce risk, support food security, generate income, and offer the opportunity to reallocate family labor to off-farm employment. Teak is the most common species in the systems, comprising 56% of the tree component. The traditional intercropping practice of tumpangsari is an important aspect of the systems, enabling farmers to respond to market opportunities for annual crops, facilitating the production of short-term to long-term returns. Besides food products for home consumption, smallholder teak systems generate 40% of overall household income from agriculture and timber products. The collection and processing of teak seed can also provide significant income for farm families. Smallholder teak systems have become an important source of raw material for the furniture industry in central Java. While the current role and potential for smallholder teak systems is good, there are some significant impediments. Chief among these are poor silvicultural management, limited market links, and policy disincentives.

To strengthen the contribution of smallholder teak systems to rural development and enhancement of livelihoods, farmers could adopt the following recommendations. Thinning should be conducted when trees are 5–6 years-old to reduce tree density to 625 per ha. In the case of initial spacing of 3 x 3 m or 2.5 x 2.5 m, that would be a thinning of 40% and 60%, respectively. Pruning to 60% of total tree height should be conducted when trees are 5–6 years-old. Branches should be pruned near the bole without leaving branch stubs. If trees originate from coppice, multiple stems should be thinned to the single healthiest stem. When planting, farmers should use the best germplasm available. Adopting these silvicultural practices would enable farmers to produce bigger, better quality teak more quickly than current practices. Farmers could also improve their marketing practices by accessing information, learning market specifications, engaging in group marketing, and instituting minimum diameter standards for harvesting. Government, support agencies and industry all have a role to play in facilitating smallholders' adoption of better silvicultural and marketing practices. Government and support agencies can provide silvicultural training and extension services. Both government agencies and industry can provide access to log grading and pricing systems used in the timber industry. Industry could work with farmer marketing groups to reward the production of better quality timber and reduce transaction costs for the benefit of farmers, traders, and themselves. Finally, government agencies could work to improve policy disincentives that inhibit smallholders' motivation to improve the management of their teak systems. These conclusions and recommendations are applicable to smallholder teak and tree-farming systems in other locations in Indonesia and across the tropics.

References

Anabarasu C, N Dutta, K Sharma, M Rawat. 2004. Response of goats to partial replacement of dietary protein by leaf meal mixture containing, *Leucaena leucocephala, Morus alba* and *Tectona grandis*. *Small Ruminant Research* 51(1): 47–56.

Anabarasu C, N Dutta, K Sharma. 2001. Use leaf meal mixture as a protein supplement in rations of goats fed wheat straw. *Animal Nutrition and Feed Technology* 1(2): 113–123.
Aoudji AKN, A Adegbidi, JC Ganglo, V Agbo, ASI Yevide, C De Canneniere, P Lebailly. 2011. Satisfaction across urban consumers of smallholder-produced teak (*Tectona grandis* L.f.) poles in South Benin. *Forest Policy and Economics* 13(8): 642–651.
Bhat KM, HO Ma. 2004. Teak growers unite! *ITTO Tropical Forest Update* 14(1): 3–5.
Bhuyan R, CN Saika, KK Das. 2004. Commercially adoptable process for manufacturing natural dyes for cotton. *Natural Product Radiance* 3(1): 6–11.
Chakraborty MK, A Bhattacharjee. 2003. Plants used for thatching purpose by the tribals of Purulia District, West Bengal, India. *Journal of Economic and Taxonomic Botany* 27(3): 571–572.
Cornelius JP, F Mesén, ST Ohashi, N Leão, CE Silva, LJ Ugarte-Guerra, KE Wightman. 2010. Smallholder production of agroforestry germplasm: experiences and lessons from Brazil, Costa Rica, Mexico and Peru. *Forests, Trees and Livelihoods* 19(3): 201–216.
De Vriend J. 1998. Teak: An exploration of market prospects and the outlook for Costa Rican plantations based on indicative growth tables. Thesis. Sub-Department of Forestry, Department of Environmental Sciences, Wageningen Agricultural University, the Netherlands.
Filius AM. 1997. Factors changing farmers' willingness to grow trees in Gunungkidul (Java, Indonesia). *Netherlands Journal of Agricultural Sciences* 45: 329–345.
Ewasechko AC. 2005. *Upgrading the Central Java wood furniture industry: a value-chain approach*. International Labor Organization, Manila.
Gupta R, MG Vairale, RR Deshmukh, PR Chaudhary, SR Wale. 2010. Ethnomedical uses of some plants by Goad tribe of Bhandara district, Maharashtra. *Indian Journal of Traditional Knowledge* 9(4): 713–717.
Gupta VC, SJ Hussain, S Imam. 1997. Important folk-medicinal plants and traditional knowledge of tribals of Aurangabad and Nasik forest divisions of Maharashtra, India. *Hamdard Medicus* 40(2): 59–61.
Holding-Anyonge C, JM Roshetko. 2003. Farm-level timber production: orienting farmers towards the market. *Unasylva* 212 (54): 48–56
Kallio MH, M Kanninen, H Krisnawati. 2012. Smallholder teak plantations in two villages in Central Java: Silvicultural activity and stand performance. *Forest, Trees and Livelihoods* 21(3): 158–175.
Kanninen M, D Perez, M Montero, E Viquez. 2004. Intensity and timing of first thinning of *Tectona grandis* plantations in Costa Rica: results of a thinning trial. *Forest Ecology and Management* 203: 89–99.
Kenny AL. 2007. Optimal land allocation of maize, cassava and teak for small landholders in southern Togo, West Africa. MS Thesis. Michigan Technological University, Houghton, USA.
Kollert W, L Cherubini. 2012. *Teak resources and market assessment 2010 (*Tectona grandis *Linn. F.)*. Food and Agriculture Organization, Rome.
Krishnapillay B. 2000. Silviculture and management of teak plantations. *Unasylva* 201(51): 14–21.
Majumdar M. 2005. Evaluation of *Tectona grandis* leaves for wound healing activity. Rajiv Gandhi University of Health Sciences, Bangalore, India.
Midgley S, M Blyth, K Mounlamai, D Midgley, A Brown. 2007. *Towards improving profitability of teak in integrated smallholder farming systems in northern Laos.* ACIAR Technical Reports 64. Australian Centre for International Agricultural Research, Canberra.

Mittelman, A. 2000. Teak planting by smallholders in Nakhon Sawan, Thailand. *Unasylva* 201(51): 62–65.

Nawir AA, Murniati, L Rumboko. 2007. Past and present policies and programmes affecting forest and land rehabilitation initiatives. In: Nawir AA, Murniati, L Rumboko, eds. *Forest rehabilitation in Indonesia: Where to after more than three decades?* Center for International Forestry Research, Bogor, Indonesia.

Newby JC, RA Cramb, S Sakanphat, S McNamara. 2012. Smallholder teak and agrarian change in Northern Laos. *Small-scale Forestry* 11(1): 27–46.

Nibbering JW 1999. Tree planting on deforested farmlands, Sewu Hills, Java, Indonesia: Impact of economic and institutional changes. *Agroforestry Systems* 46: 65–82.

Osemeobo GJ. 1989. An impact and performance evaluation of smallholder participation in tree planting, Nigeria. *Agricultural Systems* 29(2): 117–138.

Pandey D, C Brown. Teak: A global overview. *Unasylva* 201(51): 3–13.

Perdana A, JM Roshetko, I Kurniawan. 2012. Forces of competition: smallholding teak producers in Indonesia. *International Forestry Review:* 14 (2): 238–248.

Perhutani. 2010. *Annual Report 2010*. Perum Perhutani, Jakarta.

Pramono AA, MA Fauzi, N Widyani, I Heriansyah, JM Roshetko. 2011. *Management of community teak forests: a field manual for farmers*. Center for International Forestry Research, World Agroforestry Centre (ICRAF) Southeast Asia Regional Program, Forestry Research and Development Agency, Bogor, Indonesia.

Purnomosidhi P, JM Roshetko, A Prahmono, S Moestrup. 2012. *Direktori usaha pembibitan tanaman buah, kayu dan perkebunan di Propinsi Lampung* (*edisi II*). World Agroforestry Centre (ICRAF) Southeast Asia Regional Program, Bogor, Indonesia; Winrock International, USA; Faculty of Life Sciences, University of Copenhagen, Denmark.

Reddy GVN, MR Reddy. 1984. Utilization of fallen dry teak leaves (*Tectona grandis*) as roughage source in complete pelleted rations of sheep. *Indian Journal of Animal Sciences* 54(9): 843–848.

Roda JM, P Cadène, P Guizol, L Santoso, AU Fauzan. 2007. *Atlas Industri Mebel Kayu Di Jepara, Indonesia*. Center for International Forestry Research, Bogor, Indonesia.

Roemantyo HS. 1990. Ethnobotany of the Javanese incense. *Economic Botany* 44(3): 413-416.

Rohadi D, JM Roshetko, A Perdana, M Blyth, N Nuryartono, N Kusumowardani, AA Pramono, N Widyani, A Fauzi, J Sasono, P Sumardamto, P Manalu. 2011. *Improving economic outcomes for smallholders growing teak in agroforestry systems in Indonesia*. Australian Centre for International Agricultural Research, Canberra.

Rohadi D, Kallio M, Krisnawati H, Manalu P. 2010. *Economic incentives and household perceptions on smallholder timber plantations: Lessons from case studies in Indonesia*. Paper presented at the International Community Forestry Conference. Montpellier, France.

Roshetko JM, A Astho, D Rohadi, N Widyani, GS Manurung, A Fauzi, P Sumardamto. 2012. Smallholder teak systems on Java, Indonesia: income for families, timber for industry. In: SR Meyer, ed. *IUFRO Small-Scale Forestry Conference 2012: Science for Solutions*. University of Massachusetts, Amherst, 24–27 September. p. 162–167.

Roshetko JM, GS Manurung. 2009. *Smallholder teak production systems in Gunungkidul, Indonesia*. Poster. Second World Congress of Agroforestry, Nairobi.

Roshetko JM, DJ Snelder, RD Lasco, M van Noordwijk. 2008a. Future challenge: a paradigm shift in the forestry sector. In: DJ Snelder , R Lasco, eds. *Smallholder tree growing for rural development and environmental services*. Springer, London. p. 453–485.

Roshetko JM, Mulawarman, A Dianarto. 2008b. Tree seed procurement-diffusion pathways in Wonogiri and Ponorogo, Java. *Small-scale Forestry* 7:333–352.
Roshetko JM, RD Lasco, MD Delos Angeles. 2007. Smallholder agroforestry systems for carbon storage. *Mitigation and Adaptation Strategies for Global Change* 12:219–242.
Roshetko JM, P Purnomosidhi, Mulawarman. 2005. Farmer Demonstration Trials (FDTs): Promoting tree planting and farmer innovation in Indonesia. In: Gonsalves J, T Becker, A Braun, J Caminade, D Campilan, H De Chavez, E Fajber, M Kapiriri, R Vernooy, eds. *Participatory research and development for sustainable agriculture and natural resource management: a sourcebook.* International Potato Center, Laguna, Philippines; International Development Research Centre, Ottawa; International Fund for Agricultural Development, Rome. p. 384–392.
Roshetko JM, Mulawarman, P Purnomosidhi. 2004. *Gmelina arborea*: a viable species for smallholder tree farming in Indonesia? *New Forests* 28: 207–215.
Sabastian, G.E., 2012. Enhancing the sustainability of smallholder timber production systems in the Gunungkidul region, Indonesia. PhD Thesis, Australian National University, Canberra, Australia.
Sabastian G, P Kanowski, D Race, E Williams, J Roshetko. 2012. The influence of the household and farm attributes on adoption of smallholder timber production systems in the Gunungkidul region, Indonesia. In: SR Meyer, ed. *IUFRO Small-Scale Forestry Conference 2012: Science for Solutions*. University of Massachusetts, Amherst, USA, 24–27 September. p. 176–181.
Scherr SJ. 1995. Economic factors in farmer adoption of agroforestry: patterns observed in Western Kenya. *World Development* 23(5): 787–804.
Simatupang MH. 2000. Some notes on the origin and establishment of teak forest (*Tectona grandis* L.F.) in Java, Indonesia. In: *Proceedings of the Third Regional Seminar on Teak. Potential and opportunities in marketing and trade of plantation teak: challenges for the new millennium.* Yogyakarta, Indonesia, 31 July–4 August.
Sharma SK. 1999. Plants used as henna dye by the Bhils of southern Rajasthan. *Journal of Economic and Taxonomic Botany* 23(2): 257.
Siddiqui MB, MM Alam, W Husain. 1989. Traditional treatment of skin diseases in Uttar Pradesh, India. *Economic Botany* 43: 480–486.
Soerianegara I, Mansuri. 1994. Factors which determine the success of regreening in Gunungkidul, Central Java. *Journal of Tropical Forest Science* 7(1): 64–75.
Van Der Poel P, H Van Dijk. 1987. Household economy and tree growing in upland Central Java. *Agroforestry Systems* (5): 169–184.
Widiawati D. 2009. The revival of the usage of natural fibers and natural dyes in Indonesian textiles. *Journal of Visual Arts and Design* 3(2):115–128.
Wiersum KF 1982. Tree gardening and taungya on Java: Examples of agroforestry techniques in the humid tropics. *Agroforestry Systems* 1: 53–70.
Zanin DK. 2005. Feasibility of teak production for smallholders in eastern Panama. MS Thesis. Michigan Technological University, Houghton, USA.

Figures

Figure 1. Map of Gunungkidul district (Yogyakarta Special Region)

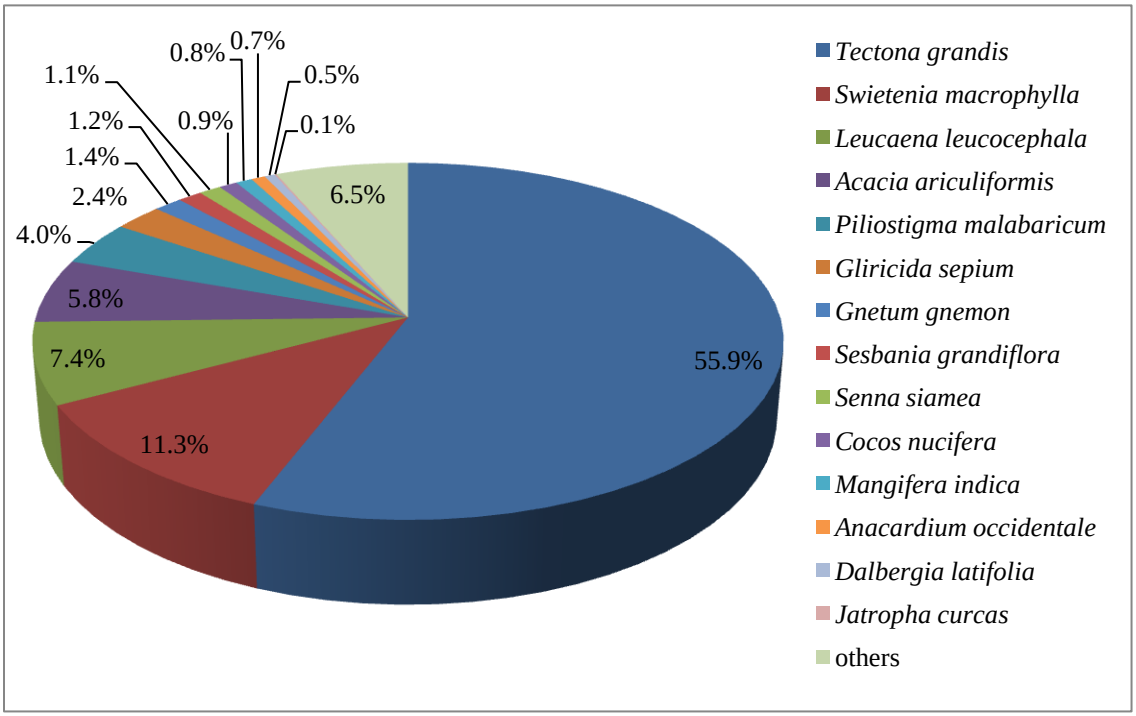

Figure 2. Species composition of smallholder teak systems in Gunungkidul, Yogyakarta

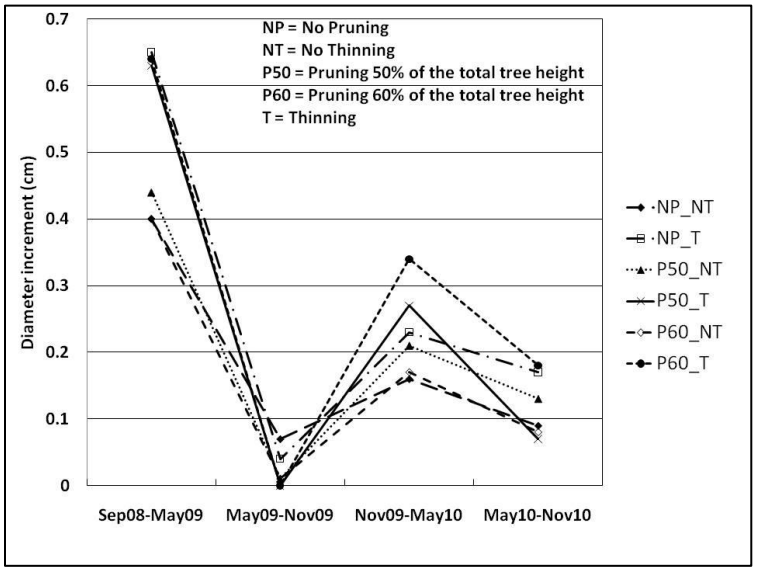

Figure 3. The effect of thinning and pruning on teak tree diameter growth

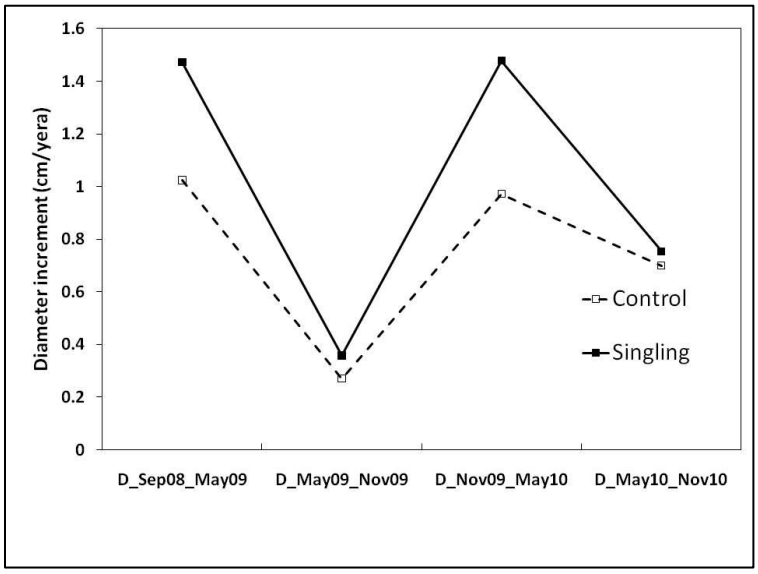

Figure 4. The effect of singling on teak tree diameter growth

Tables

Table 1. Summary of smallholder teak systems

Teak system	Percent of teak systems	Farm size (ha)	Tree density (ha)	Tree species (farm)
Tegalan	50.6%	0.47	1072	8
Pekarangan	21.9%	0.24	1177	13
Kitren	21.9%	0.31	1532	5
Line plantings (agric land)	4.8%	0.31	138	7

Table 2. Prices for farm-grown teak in Gunungkidul in 2008

Age (year)	DBH (cm)	Price accepted by producers (USD/standing tree)	Log volume after processing by traders (m^3)	Log price received by traders (USD)
10	12 – 18	3 – 6	0.045 - 0.189	3 – 25
15	13 – 31	5 – 30	0.060 - 0.515	6 – 123
20	21 – 45	10 – 265	0.307 - 1.061	57 – 284
25	29 – 49	20 – 296	0.320 - 1.321	54 – 329

Table 3. Farmer demonstration trials by landowner, location and silvicultural treatment

No.	Landowner	Hamlet, village, sub-district	Silvicultural treatment
1	Subardi	Temon, Purwosari, Giripurwo	• Coppice thinning (control and singling)
2	Karsukiyo	Karangduwet, Paliyan	• Coppice thinning (control and singling)
3	Kardi Utomo	Karangduwet, Paliyan	• Coppice thinning (control and singling)
4	Citro Widarso	Sokoliman I, Bejiharjo, Karang Mojo.	• Thinning (control) • Pruning (control, 50% and 60% pruned)
5	Suwarto	Sokoliman I, Bejiharjo, Karang Mojo.	• Thining (control and ± 40% thinned) • Pruning (control, 50% and 60% pruned)
6	Giyono/Budiyono	Munggur, Ngawis, Karang Mojo.	• Thining (control and ± 40% thinned) • Pruning (control, 50% and 60% pruned)