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Trade-offs analysis for possible timber-based agroforestry scenarios using native trees in the Philippines

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Abstract To assess possible new agroforestry scenarios the tree–soil–crop interaction model in agroforestry systems (WaNuLCAS 3.01) was used based on-site specific data collected from Tabango (Central Philippines). Three native timber trees (*Shorea contorta* Vid., *Pterocarpus indicus* Juss., and *Vitex parviflora* Willd.) and one widely spread exotic specie (*Swietenia macrophylla* King.) were simulated under different intercrop scenarios with maize (*Zea mays* L.) and subsequently compared. Model simulation results quantified and explained trade-off between tree and crop. For example, higher tree densities will lead to a loss of crop yield that is approximately proportional to the gain in wood volume. However, beside this trade-off effect, there is considerable scope for tree intercropping advantage under a fertilization scenario, with systems that yield about 50% of the maximum tree biomass still allowing 70% of monoculture maize yield. Maximum tree yield can still be obtained at about 20% of the potential crop yield but intermediate tree population densities (400 trees ha^{-1}) and the resulting larger stem diameters may be preferable over the larger total tree biomass obtained at higher tree densities. Another advantage from intercropping systems is that trees directly benefit from the inputs (i.e., fertilizer) that are applied to the crops. The three native trees species studied have different performance in relation to productivity but are similar to (or even better than) *S. macrophylla*.

Keywords Native timber trees · Intercropping · Tree–soil–crop interactions · Trade-offs

Introduction

On degraded land it is hard to maintain a farming lifestyle based on annual food crops alone (Ong et al. 1996). Farmers struggle to overcome agricultural constraints to maintain production, or adapt their choice of crops to the conditions of a place, i.e., farmers switch from maize to cassava when soils become degraded (Agpaoa et al. 1976). According to Young (1997) trees introduced into annual cropping systems help to overcoming degraded soil conditions by (1) providing a slowly decomposing litter layer that protects the soil from splash impacts of rainfall, reduces runoff and maximise water and nutrient resource use, (2) adding substantial amounts of organic matter through litter layer and root turnover, allowing for a gradual recovery of soil structure; and (3) capturing nutrients from deeper soil layers or intercepting current leaching losses, depending on their root distribution.

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Trees have to represent direct as well as indirect economic value, to offset their resource capture in competition with annual crops (Huxley 1999). Firstly, farmers strongly favor a species from which high returns have been obtained in the past. Secondly, farmers almost invariably choose a species for which planting material is low in cost and readily available (Nair 1993). As a result, most common species found in upland farms in the Philippines are fast growing exotic species as: Gmelina (*Gmelina arborea*), Mangium (*Acacia mangium*), Mahogany (*Swietenia macrophylla*) and Falcata (*Paraserianthes falcataria*).

However, many smallholders in the Philippines are starting to plant high quality timber trees even if rotations are longer, because of their compatibility with associated crops and the higher potential market price of quality products (Schute 2002). *S. macrophylla* K. (Mahogany) is a good example of well promoted good quality exotic timber tree, while there is a vast number of native timber species with high market potential that have not yet been explored. Lack of scientific information of native tree species, have constrain the utilization and promotion of those species on traditional tree domestication programs (Leakey and Simons 1998). Available data that classify trees by their broad climatic requirements and types of use is generally not sufficiently precise to guide local choice, especially for some native tree species in early stages of domestication (Roshetko and Evans 1999).

According to Roshetko and Evans (1999) to thoroughly assess the potential of promising and preferred native tree species for on-farm domestication should first take into consideration: plant spacing and pattern, management practice and suitability or growth performance in varying site conditions. The function, patterns and management systems of smallholder timber plantations are markedly different from those found in natural forest, government-sponsored reforestation and plantation forestry (Harrison et al. 2002). To better serve these functions, trees may be incorporated in various densities and arrangements (Garrity 1997). This set of interrelated decisions of a tree growing practice will eventually define the attributes of the appropriate tree species to be selected for on-farm planting to perform the intended function (Raintree 1991).

Risk reduction is other important objective in livelihood strategies of small-scale farmers (Amacher et al. 1993). Households' attitudes toward risk and expectation of uncertain gains from adoption were among the most critical factors in adoption of alternative land-use system (FAO 1986). However, the degree to which households will try to reduce the amount of risk depends on their resource position. For example, the associate risks involved in growing trees differ from those for food crops (i.e., uncertainty of long term trends in prices), this is in itself one of the potential advantages of agroforestry, but also poses a challenge for farmers converting part of their farm to agroforestry.

Even though farmers can instinctively anticipate crop yield losses as trees grow, they would likely be unable to accurately predict the period of viable intercropping and the net profit over the tree rotation (Cambel et al. 1996). Thus, during a farm planning period farmers will have to make decisions at a number of levels. Some decisions refer to the field scale on a multiyear basis (strategic choices of tree species and spacing), others to annual decisions at field scale (tactical decisions on cropping pattern and fertilization), a third group to household and landscape scale considerations that involve the tradeoffs between productivity and environmental service provision at field scale, and the best use of household level resources of land and labor (van Noordwijk et al. 2004). Most, if not all, of these decisions are beyond the reach of a purely empirical approach, as the number of options is too vast. The use of existing simulation agroforestry models as WaNuLCAS 3.01 (van Noordwijk and Lusiana 1999) to explore a broad range of options and zoom in on the combinations that are most likely to meet farmers' expectations comes as a logical alternative.

Therefore, this study was designed with two main objectives: (1) evaluate biophysical feasibility and sustainability for timber based agroforestry system with native species compare to monoculture (trees or crops) scenarios (2) assess the trade-offs between trees and crops from a wide array of possible management options.

Methodology

WaNuLCAS 3.01 core module: set of input parameters

To be able to run and produce a simple regular output WaNulCAS 3.01 needs a minimum set of input parameters named core module.

Climate conditions

Daily rainfall data were collected during year 2004 from Manlawaan, municipality of Tabango (Leyte, Cental Philippines). Annual average rainfall is 2200 mm with a monthly distribution that clearly identifies a wet (June to December) and dry (January to May) season. Model default air and soil temperature were used for the simulation due a lack of data in this respect.

Soil profile

Soil physical and chemical properties were based on a catena study conducted in the municipality of tabango by the Department of Agronomy and Soil Science, College of Agriculture, Leyte State University (Gemao et al. 2003). Characterization of soils was based on four soil profiles across the landscape catena: summit, upper-slope, lower-slope and button-slope.

Soil is represented in the model in four layers, the depth of which was chosen based on average values. Soil physical and chemical characteristics, were derived via WaNuLCAS 3.01 pedotransfer functions from soil texture, bulk density and soil organic matter content from field data collected (Table 1). The nutrient balance of the model includes inputs from fertilizer (specified by amount and time of application), atmospheric N fixation a mineralization of soil organic matter and fresh residues.

Tree functional parameters

To be able to run the model, it was first necessary to calibrate collected native tree parameters to confirm predicted tree growth performance by WaNuLCAS 3.1. Each tree species was run for 10 years period in a tree monoculture simulation and predicted results were compared with empirical field plantations measurements. Native tree parameters were collected from monoculture tree plantation because it was not possible to found mature trees in an agroforestry context from the study area. To compensate this lack of information, the study makes the assumption that if the model has a good predictive power of timber species in monoculture directly translates to good predictive power of timber species in agroforestry for two reasons: (1) based on experience, the negative interactions of maize intercropping to timber tree growth are not remarkable for long term simulations (15 years), and (2) the positive interactions of maize intercropping to timber tree growth are essentially indirect effects as land preparation or inputs applied.

The WanFBA model (van Noordwijk and Mulia 2002) was used in this study to develop allometric equations to estimate above ground tree biomass for *Shorea contorta* V., *Pterocarpus indicus* J., and *Vitex parviflora* W. Aboveground biomass allometric equations as derived from the WanFBA module were included into the set of WaNulCAS 3.01 input parameters. These functions were developed and validated based on reference allometric equations derived from destructive sampling methods collected from tree plantation on the study area (Table 2).

Other required tree functional parameters included into the model based on field measurements are: specific leaf area (SLA), leave area index (LAI), canopy diameter and shape. Parameters such as maximum growth rate, maximum daily mobilizable fraction of growth reserves or cumulative literfall equations were calibrated by fitting predicted to observed relative biomass functions (Mulia et al. 2001). Belowground parameters, as root type and biomass were taken from default values coming from WaNuLCAS 3.01 tree library.

Swietenia macrophylla King. (Mahogany) was included in the study as the threshold for tree growth reference. Mahogany was selected because is an exotic timber tree vastly introduce in the Philippines

Table 1 Soil physical and chemical characteristics of the study site included in WaNuLCAS core module

Soil depth (cm)	Clay (%)	Silt (%)	Organic matter (%)	Bulk density (g cm^{-3})	P_{Olsen} (mg cm^{-3})	Soil texture
0–10	21.4	60.9	2.68	1.387	10.52	Light clay
10–40	21.6	59.8	1.43	1.429	7.90	Light clay
40–60	24.0	57.6	1.10	1.423	8.26	Light clay
60–100	22.2	58.9	0.99	1.442	8.12	Light clay

Table 2 Aboveground biomass allometric equations ($Y = ad^b$) to simulate tree growth in WaNuLCAS 3.01 (where "d" refer to DBH at 1.3 m)

Allometric equations (kg)	*Shorea contorta*	*Vitex parviflora*	*Pterocapus indicus*
(a) Factor for total biomass	0.084	0.118	0.177
(b) Factor for total biomass	2.548	2.493	2.440
(a) Factor for wood biomass	0.036	0.025	0.031
(b) Factor for wood biomass	2.794	3.074	2.968
(a) Factor for leaf biomass	0.120	0.015	0.011
(b) Factor for leaf biomass	1.928	2.466	2.340

and has similar growth and wood market characteristics than the three native trees selected. Tree functional parameters for Mahogany were taken for WaNuLCAS 3.01 tree library.

Crop selection

Maize (*Zea mays* L.) was selected as the crop for the intercrop scenarios because is the most preferred food crop among upland farmers in the study site (Groestschel et al. 2001). Two cropping seasons per year were set for the model simulation according farmers practices based on field observations. No changes were made in the default parameters for Maize (*Zea mays* L.) from WaNuLCAS 3.01 crop library.

Management options

WaNuLCAS 3.01 was used to provide simulations scenarios of a wide array of realistic management options that make a transition from crop monoculture towards tree-dominated systems. Thus, three possible land uses scenarios were characterized and simulated into the model for comparison purposes: (1) maize monocropping, (2) hedgerow tree intercropping and (3) tree monoculture (Table 3).

All three scenarios were run with WaNuLCAS 3.01 for a period of 15 years (30 cropping seasons). A simulation period of 15 years was considered because this is the normal tree rotation for medium-term species (Valdez 1991). For maize monocropping and tree intercropping systems simulations outputs were compare with and without fertilizer. For those systems under a fertilization conditions, N and P were applied only to the crop at an amount of 45 kg N ha^{-1} and 30 kg P_2O_5 ha^{-1} based on farmers' practices (Stark 2003). Both, N and P were applied in one time at planting time for every cropping season. For tree monoculture plantations, the simulation was run after monocropping maize in a non fertilizer scenario for four and a half years (estimated period when crop yield will declined below the profitable threshold under non-fertilizer conditions). If applied to hedgerow intercropping systems, WaNuLCAS 3.01 allows for the evaluation of crop growth at different distances form the tree hedgerow. With the objective to see the effect on how tree planting pattern affects the crop performance, the model was run at five different tree densities (50, 100, 200, 400, 800 trees ha^{-1}) as a result of combining three different levels of alley and intrarow spacing (Table 4).

System analyses

Simulation model outputs were analyzed from a system perspective with two different approaches: (1) Trade-off analysis between tree growth and crop yield; (2) equivalent area index (EAI). Results from these two analyses will provide the necessary information to evaluate the feasibility and sustainability of all systems simulated.

Trade-off analysis between tree growth and crop yield

An efficient and innovative way of evaluating an agroforestry system is to plot crop versus tree yield (Fig. 1) (SAFODS 2005). If the tree-crop combinations are substantially above ($X > 1$) the straight 1:1 trade-off curve, it means that there is a net positive interaction within the system. However, when the points are below ($X < 1$) suggest that there is virtually no intercropping advantage. If after accounting for this intercept, a positive curvature remains when tree spacing is widened, suggest that there is indeed a

Table 3 Description of land use simulation scenarios run with WaNuLCAS 3.01

Simulation scenarios	Code	Time (years/ cropping seasons)	Fertilizer (kg ha^{-1})	Crop	Tree sp.
I. Maize moncropping	Maize MC + Fertz	15 (30c.s)	45 N–30 P	Maize	–
	Maize MC − Fertz	15 (30c.s)	–	Maize	–
II. Tree intercropping	Tree IC + Fertz	15	45 N–30 P	Maize	*S. contorta*
	Tree IC + Fertz	15	45 N–30 P	Maize	*V. parviflora*
	Tree IC + Fertz	15	45 N–30 P	Maize	*P. indicus*
	Tree IC + Fertz	15	45 N–30 P	Maize	*S. macrophyla*
	Tree IC − Fertz	15	–	Maize	*S. contorta*
	Tree IC − Fertz	15	–	Maize	*V. parviflora*
	Tree IC − Fertz	15	–	Maize	*P. indicus*
	Tree IC − Fertz	15	–	Maize	*S. macrophyla*
III. Tree monoculture	Tree MC	15	–	–	*S. contorta*
	Tree MC	15	–	–	*V. parviflora*
	Tree MC	15	–	–	*P. indicus*
	Tree MC	15	–	–	*S. macrophyla*

Table 4 Tree spacing applied for WaNuLCAS 3.01 simulation

Alley spacing (meters)	Intrarow spacing (meters)	Planting pattern (meters)	Tree density (trees ha^{-1})
20 (Wide alley)	2.5	20 × 2.5	200
	5.0	20 × 5.0	100
	10.0	20 × 10.0	50
10 (Middle alley)	2.5	10 × 2.5	400
	5.0	10 × 5.0	200
	10.0	10 × 10.0	100
5 (Narrow alley)	2.5	5 × 2.5	800
	5.0	5 × 5.0	400
	10.0	5 × 10.0	200

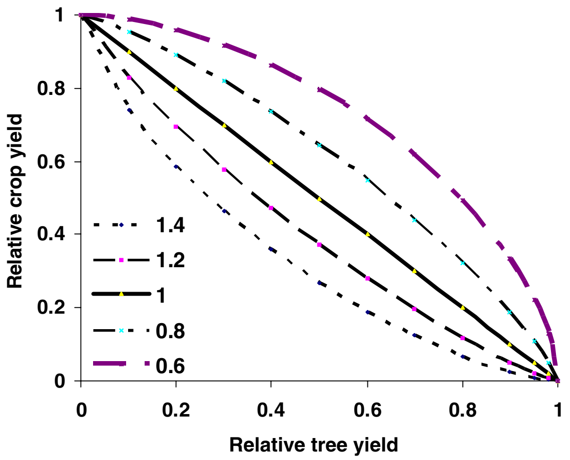

Fig. 1 Trade-off between tree and crop yield, with net negative ($X < 1$) or net positive ($X > 1$) interactions

benefit to be obtained by the intercrop combination when compared to separate monocultures.

Equivalent area index (EAI) analysis

The EAI is the second way of evaluate agroforestry scenarios and expresses the area of monocultures of trees plus crop that would be needed to achieve the same growth as obtained in intercropping (Willey and Osiru 1972). When the index is equal to or higher than one, it indicates positive interactions between the intercropped components and thus the system intercropping is technically feasible. When EAI analyses are presented on a yearly increment basis, it can be seen the way the systems changes allowing to evaluate and determine the age of tree which can still provide valuable crop yield. Calculations of the equivalent area production index (EAI) are based on the following formula:

$$\mathrm{EAI} = \mathrm{EI_t} + \mathrm{EI_c} = \left(\frac{\mathrm{PI_t}}{\mathrm{PM_t}}\right) + \left(\frac{\mathrm{PI_c}}{\mathrm{PM_c}}\right) \tag{1}$$

Where: EAI = equivalent area index of the systems; $\mathrm{EI_t}$ = equivalent index of tree area; $\mathrm{EI_c}$ = equivalent index of crop area; $\mathrm{PI_t}$ and $\mathrm{PM_t}$ = tree productivity in intercropping and monoculture systems; $\mathrm{PI_c}$ and $\mathrm{PM_c}$ = crop productivity in intercropping and monoculture systems. Productivity of tree is using wood volume, $\mathrm{m^3\ ha^{-1}}$, while for maize is dry weight of grain, $\mathrm{Mg\ ha^{-1}}$.

Results

WaNuLCAS 3.01 simulation outputs

Tree growth model calibration

Linear regression between empirical tree growth (field measurements) and predicted output (using WaNuLCAS 3.1) shows how close model results fit to linear relationships (Fig. 2). Model predictions accurately described tree growth for all three tree species with regards to stem diameter (Fig. 2a), total aboveground biomass (Fig. 2c), wood biomass (Fig. 2d) and leaves biomass (Fig. 2e). For tree height (Fig. 2b) the goodness of fit differed among species, with the largest deviations occurring for *Petrocarpus indicus*.

Length of cropping period

WaNulCAS 3.01 model includes a rule that cropping will be automatically stopped after the first crop that reached a zero or negative net benefit, so the length of cropping period is now a model output, rather than input. Therefore the number of years cropping took place became a variable influenced by tree properties, tree spacing and growth conditions, rather than being a user-determined input as such.

Model predictions show clearly different opportunities for planting maize with or without fertilizer (Fig. 3). In particular for maize monoculture in a non fertilization scenario, the cropping period is only feasible during the first 4 years (eight cropping seasons) while under a fertilization situation maize yields were constantly maintained above the threshold level (Fig. 3A.1, A.2). The effect of different tree species and planting patterns on maize cropping period was also captured by the outputs only under a fertilization scenario (Fig. 3B.1–C.1–D.1, E.1). Major differences on maize yield were found due to widening effect of the alleys rather than the intrarow distance in between trees. For instance, in planting patterns with narrow alley (5 m) maize was never feasible up to the end of the simulation, while for intermediate and wider crop alleys (10 and 20 m) maize was feasible for continuous intercropping for all tree species with the exception of *Vitex parviflora*, where yield will start to drop down after 20 cropping seasons (Fig. 3C.1).

Crop yield

If above results are converted into cumulative maize yield up to the end of the simulation, it is clearly seen that there is a trade-off between the tree and crop yields: lower tree densities lead to a proportional gain in maize productivity (Fig. 4). In a fertilization intercrop scenario, maize yield is considerably influenced by tree density, spacing arrangements and species selected for the systems. If the priority is given to the tree of the final tree-crop combination (targeting maximum tree density, 800 trees $\mathrm{ha^{-1}}$) average predicted cumulative maize yield will be 20 Mg $\mathrm{ha^{-1}}$, which represents only 1/3 from the total yield that could be harvest on a maize monoculture scenario. Instead, if the priority is given to the crop (targeting minimum tree density, 100 trees $\mathrm{ha^{-1}}$) the system still allows close to 90% of monoculture crop yield.

By contrast, based on this results, in a non fertilization scenario maize monocropping or intercropping (regardless the tree species or planting pattern) is not a feasible and sustainable option for farmers on degraded soils. The low productivity in terms of maize yield (almost 10 times less than in a fertilization scenario) shows that agroforestry options are not better than monoculture under these conditions.

Tree performance

One clear advantage for intercropping systems, as seen in these results, is that trees directly benefit from

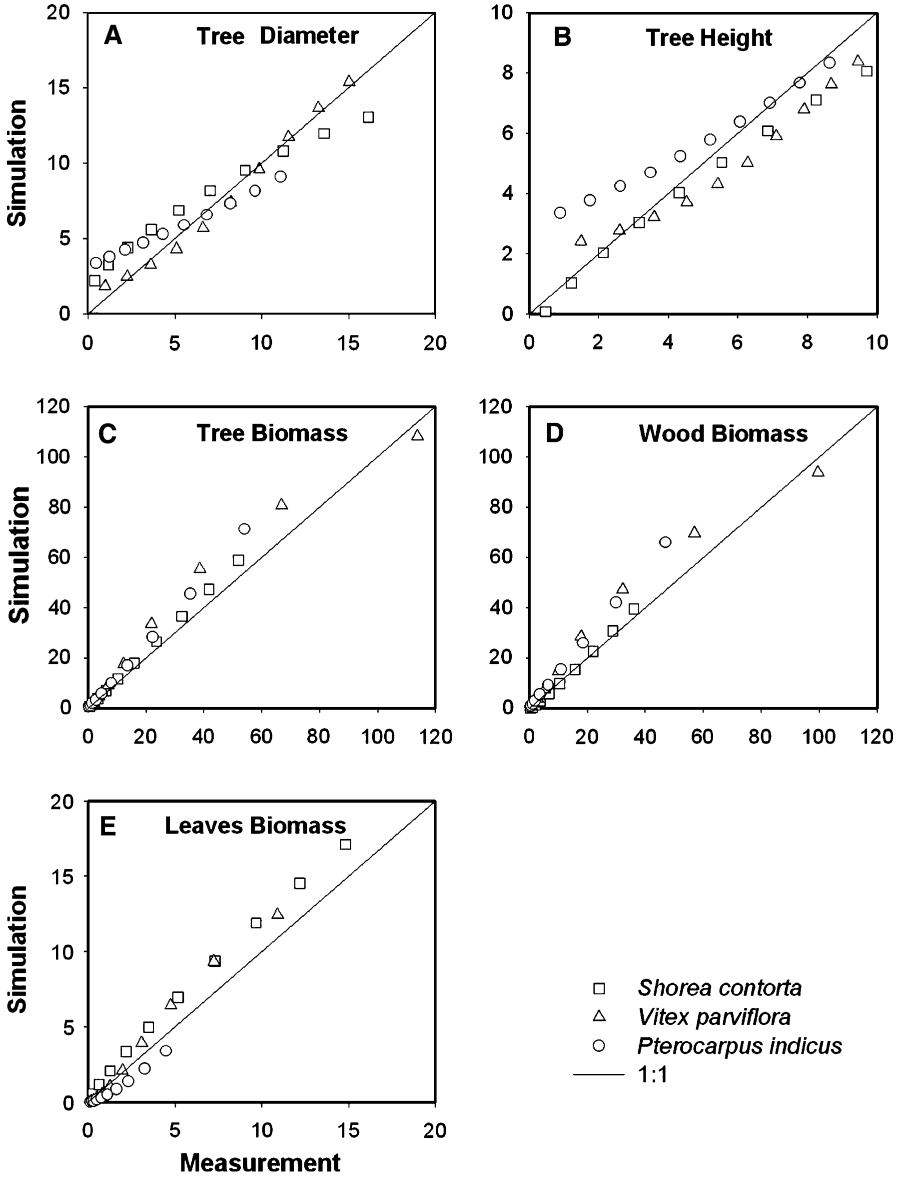

Fig. 2 Comparison of simulated and measured tree growth over a 10 years period: **a** tree diameter (cm), **b** tree height (m), **c** tree biomass (Mg ha^{-1}), **d** wood biomass (Mg ha^{-1}) and, **e** leaves biomass (Mg ha^{-1})

the inputs (i.e., fertilizer) that are applied to the crops (Figs. 5a, 6a). All tree intercrop systems under fertilization conditions, substantially increased their tree performance (in terms of wood volume and stem diameter) if compared to the same systems without fertilizer (Figs. 5b, 6b). By contrast, tree monoculture plantations have almost the same tree growth as tree intercropped system without fertilizer showing that even under these conditions there are some opportunities for simultaneous agroforestry systems (Figs. 5c, 6c). At the species level, *Ptercarpus indicus* showed the best response at higher tree density and *S. macrophylla* at lower tree densities. *S. contorta* constantly showed the lowest tree performance for all tree systems studied. Results from the simulation also show that higher tree densities produce higher wood volume but lower tree diameter growth (Fig. 6).

Systems evaluation

Trade-off analysis

All tree–crop combinations of intercrop system with fertilizer are substantially above the straight trade-off

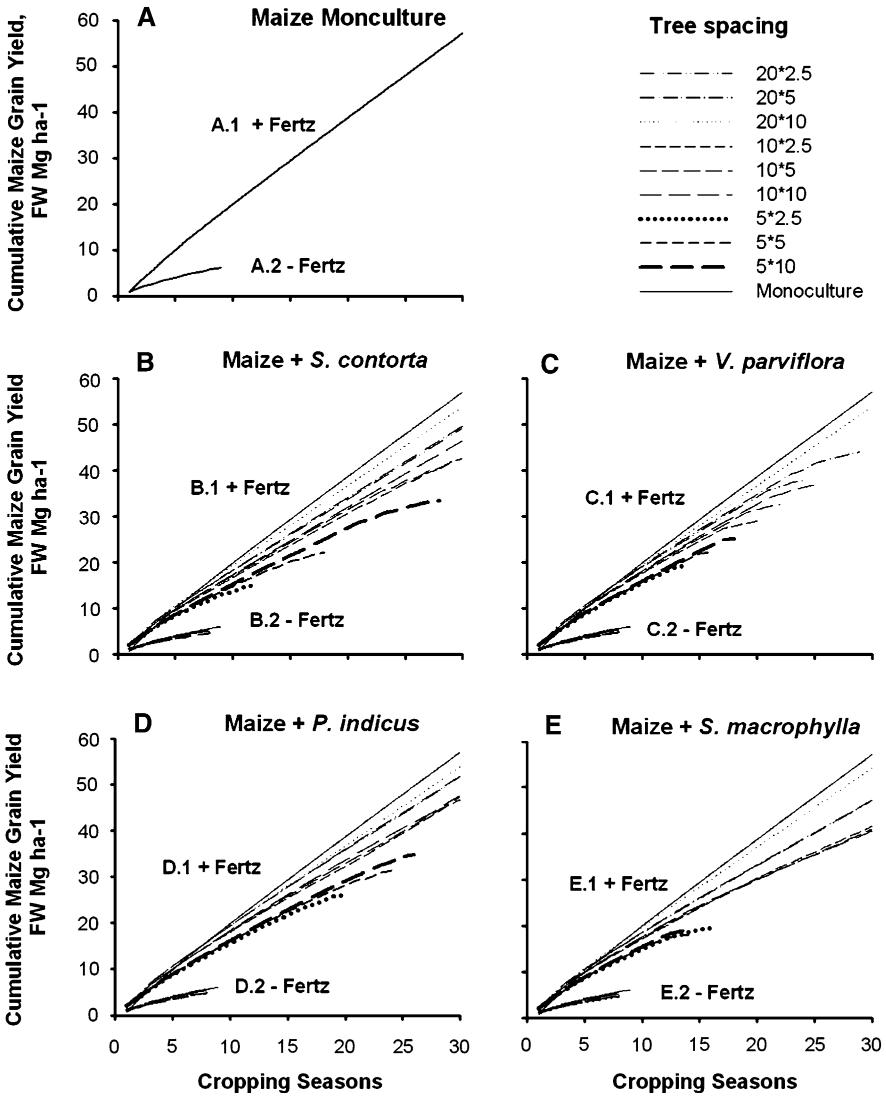

Fig. 3 Length of cropping period under various tree spacing and fertilization conditions

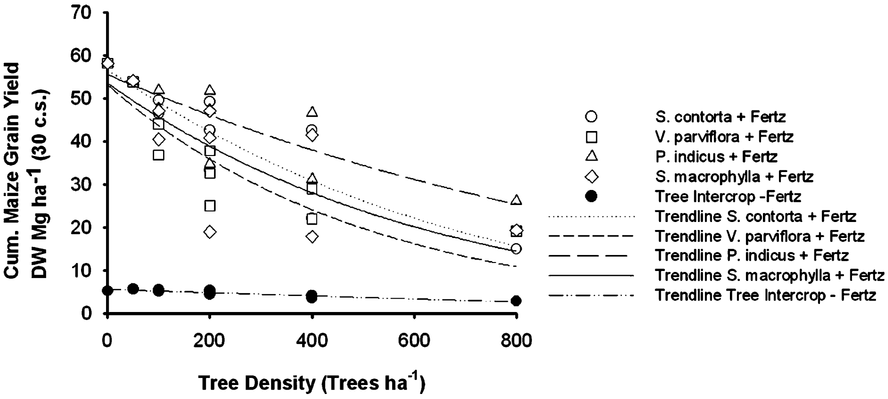

Fig. 4 Cumulative maize yield during 30 cropping seasons for monoculture and intercropping systems

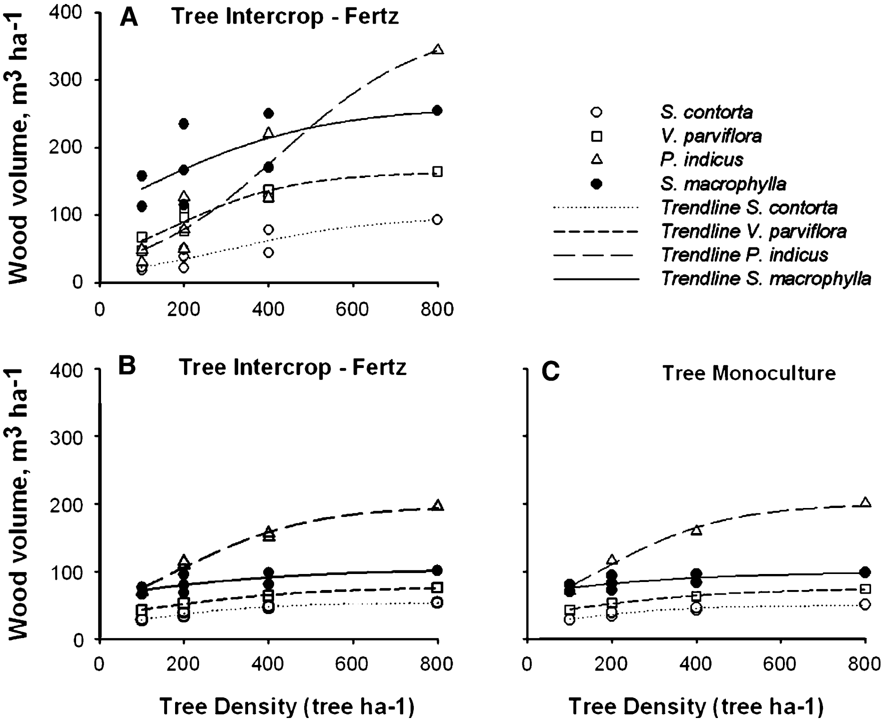

Fig. 5 Wood volume prediction for tree intercrop and monoculture systems for a period of 15 years

curve, suggesting that there is indeed a benefit to be obtained by the combination when compared to separate monocultures (Fig. 7). After accounting for this intercept, the slight positive curvature of trend line for *V. parviflora* and *S. macrophylla* that remains when tree spacing is widened, suggests a clear intercropping advantage at intermediate tree population densities for these two species.

Generally, results from trade-off analysis show that there is considerable scope for agroforestry with all tree species studied, with systems that yield about half of the maximum tree biomass still allowing 70% of monoculture maize yield. Maximum tree yield can be obtained at about 40% of the potential crop yield. Although, when low tree densities (100 trees ha^{-1}) are targeted to increase the ratio between wood volume and stem diameter for better quality wood products, intercrop systems will still allowed close to 90% of the potential maize yield. However, results shows that the intercropping advantage will also depend on the tree species and spacing selected.

Trade-off analyses under non-fertilization scenarios are not presented as crop failures meant that no intercropping advantage was obtained under these conditions, according to the model.

Equivalent area index (EAI)

As EAI analysis is presented on a yearly increment basis, results clearly show that after an initial stage (4–5 years where by definition 'wood increments' only start after the tree stem diameter reached 10 cm), the accumulating value between the tree plus crops makes all intercrop systems studied technically feasible (EAI $>$ 1) (Fig. 8). During the initial stage, where the interaction between trees and crops are very high, the system can still provide valuable crop yield but as soon as the tree yield starts to increase above the threshold level the crop will start to decline. Besides this interaction effect between the components, maize productivity was sustainable up to the end of the rotation period for all tree intercrop systems with the exception of *Vitex parviflora* (Fig. 8b). As trees benefit from the inputs applied to the crops in intercrop systems, results suggest that there is a remarkable advantage for the wood which increases the land productivity within a

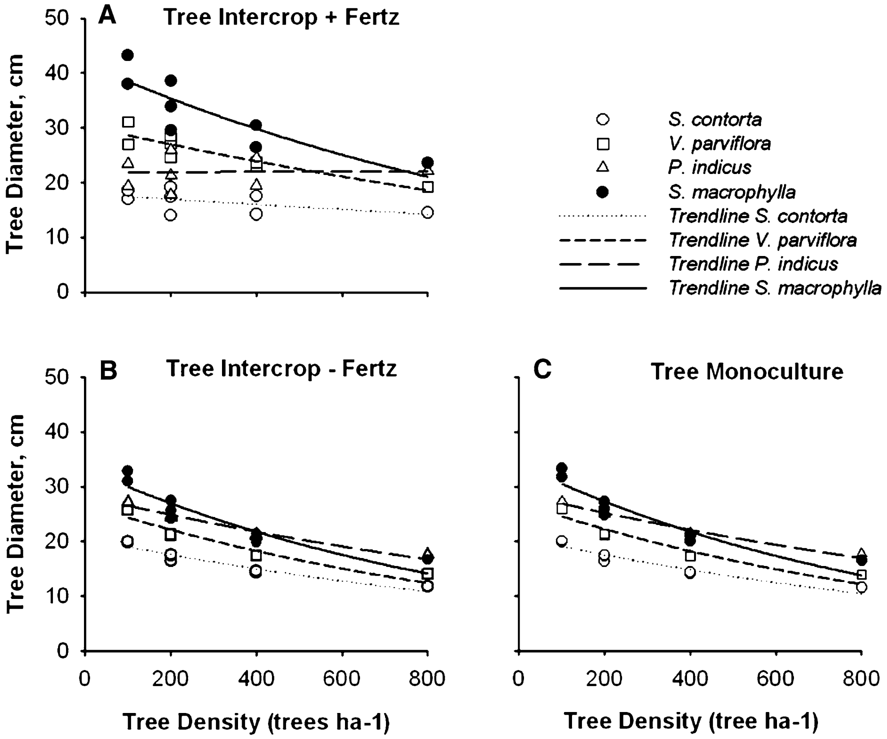

Fig. 6 Stem diameter prediction for tree intercrop and monoculture systems for a period of 15 years

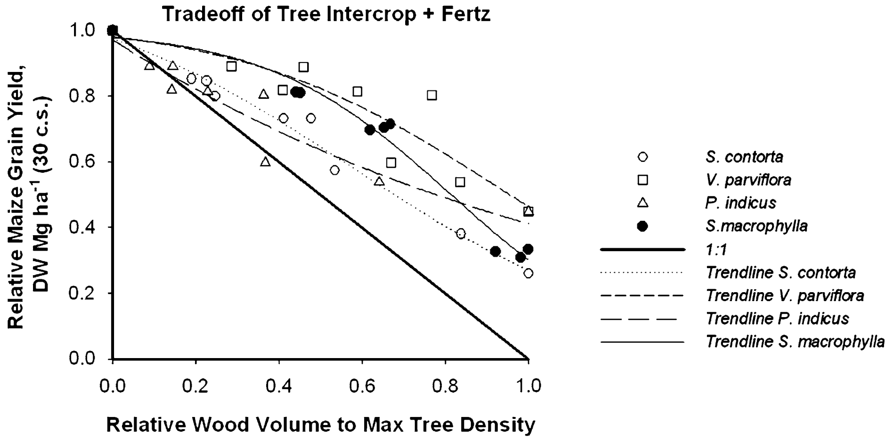

Fig. 7 Trade-off analyses between tree and crop interactions for simultaneous intercrop systems

range of 1.5–2.5 times than in unfertilized tree monoculture systems as comparison.

Discussion

Overall this study simulated different timber based agroforestry system to evaluate the technical feasibility of native trees to be intercrop with maize under a wide array of possible management options. Results presented in this paper, show that there is considerable scope for intercropping systems with native timber tree species if maize is fertilized, and that the intercropping advantage will depend on the tree species and planting pattern selected.

The effect of different tree species and planting patterns on maize cropping period was captured by the model simulations outputs. Major differences on

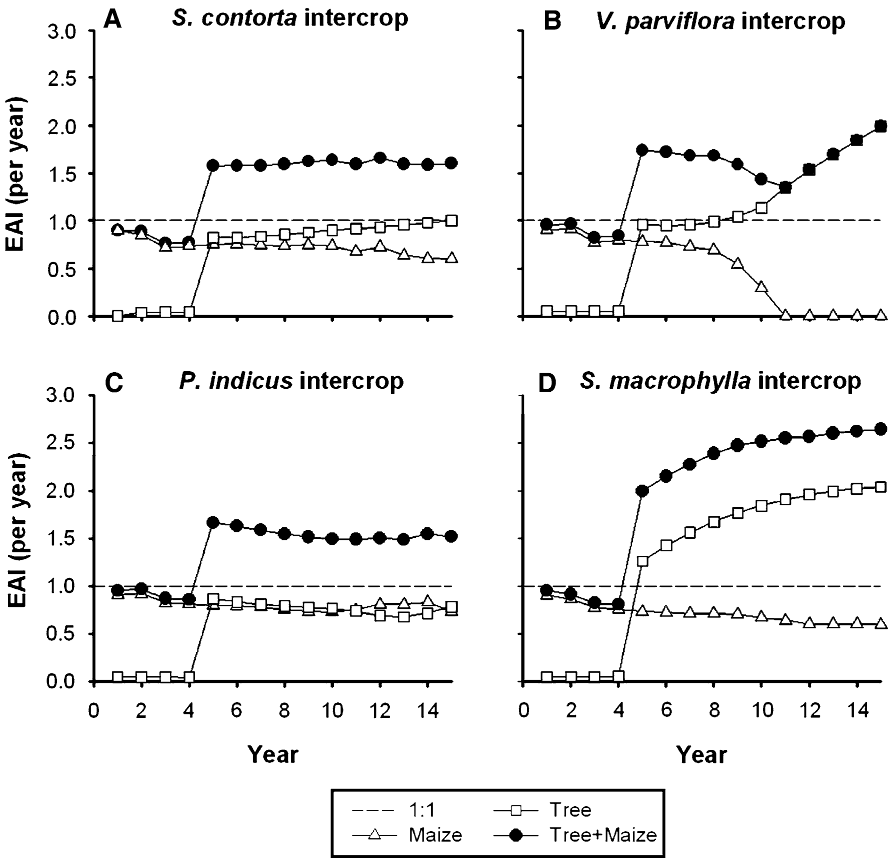

Fig. 8 Equivalent area index analysis presented on a yearly increment basis (*Note*: by definition 'wood increments' only start after the tree stem diameter reached 10 cm)

maize yield were found due to widening effect of the alleys rather than the intrarow distance in between trees. For instance, in planting patterns with narrow alley (5 m) maize was never feasible up to the end of the simulation, while for intermediate and wider crop alleys (10 and 20 m) maize was feasible for continuous intercropping. Therefore, increasing the space between tree rows makes longer intercropping possible but reduces the expected wood yield from the trees. For example, 400 trees ha^{-1} planted of *Pterocarpus indicus* at 10 × 2.5 m will produce at the end of the rotation period 124.93 m^3 ha^{-1} of wood volume; while if trees are arranged at 5 × 5 m (with the same tree density) the system will yield 220.28 m^3 ha^{-1}. This represents an increase on the tree biomass of around 40% depending on the tree species. Beside this loss on wood volume, closer intra-row spacing provides the side shading needed to promote good stem form of timber trees (Gajaseni and Jordan 1992; Huxley 1999).

The response of the model in regards to tree growth performance primarily depends on the ability of trees to utilize potential canopy space that they get in wider plant spacing and to at least partially compensate for the lower plant density by a larger size per tree. As a consequence, higher tree densities produce higher wood volume but lower tree diameter growth. Therefore, if economic value depends on individual stem diameters rather than total wood volume, economic optimization may differ from maximising productivity and lower tree densities should be considered (Sanchez 1995).

Generally all species studied, have appropriate crown shapes which allow an optimal balance among trees and crops for both ecosystem and agricultural purpose. However, not all species with those tree characteristics may be adapted to stress environments, such as poor degraded soils from the study site. For example, *Shorea contorta* show a poor response when planted under these conditions in an agroforestry situation. Possibly because *Ptercarpus indicus* is a nitrogen fixing tree and therefore reduce below ground nutrient competition, seems to be better adapted to these conditions than the other three species included in the study.

Another clear advantage of simultaneous intercropping rather than sequential monoculture systems is that trees directly benefit from the inputs (i.e., fertilizer) that are applied to the crops. All tree intercrop systems simulated by the model under fertilization conditions considerably increased their tree performance in terms of wood volume and stem diameter. For example, for *V. parviflora* and *P. indicus* maximum tree yield can be obtained at about 50% (30 Mg ha^{-1}) of the potential crop yield, while for *S. macrophylla* and *S. contorta* will be at 30% (20 Mg ha^{-1}).

By contrast, in a non fertilization scenario, maize production is not a feasible and sustainable option for farmers on degraded soils. The rapid decline of maize yields allows for only 4–5 continuous cropping seasons either for monocropping or intercropping (regardless the tree species or planting pattern) scenarios. Thus, if farmer can afford the use of fertilizer, a gradual transition from annual food crop to tree-based systems should be a more sustainable and environmentally sound alternative. This idea is in line with other studies and actors in the Philippines (Gacososcosim 1995; DENR 1998; Bertomeu 2004).

However, native timber species are one of the most risky groups to make prediction because they take long time to mature and still there is a lack of scientifically information and records. WaNuLCAS 3.01 model was used in this study to fill up that gap and make long term predictions about the suitability of novel native timber tree species for agroforestry systems. As a whole, model calculations may present a reasonable correspondence with real world options. Any of the results mentioned here would vary with parameters such as soil depth, soil texture, tree canopy characteristics and rooting pattern but the basic pattern of response to climate zones would remain determined by overall resource availability. In this sense the model can be viewed as a "null model" (Gotelli and Graves 1996) which can be used like a null hypothesis as a background against which specific data sets can be tested.

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