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2023

http://hdl.handle.net/10138/574711

Rahman, S A, Samsudin, Y B, Bhatta, K P, Aryal, A, Hayati, D, Cahya, M, Trihadmojo, B, Husain, I, Andini, S, Narulita, S, Rahman, M A, Lu, X, Emang, D, Abimbola, A I, Kustanti, A & Larjavaara, M 2023, The Role of Agroforestry Systems for Enhancing Biodiversity and Provision of Ecosystem Services in Agricultural Landscapes in Southeast Asia. in J C Dagar, S R Gupta & G W Sileshi (eds), Agroforestry for Sustainable Intensification of Agriculture in Asia and Africa. Sustainability Sciences in Asia and Africa, Sustainable Agriculture and Food Security, Springer Nature Singapore Pte Ltd., Singapore, pp. 303-319. https://doi.org/10.1007/978-981-19-4602-8_10

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Abstract

Biodiversity has a pivotal role to provide ecosystem goods and services, which is under threat due to various anthropogenic disturbances. This chapter is based on review of literature to assess the role of agroforestry to enhance biodiversity and ecosystem services in Southeast Asian agricultural landscapes. Reviewed data is analyzed through narrative qualitative and narrative comparative methods with careful compilation for scientific interpretation. Agroforestry systems can conserve species diversity and enhance ecosystem services. Farmers cultivating diverse species in agroforestry is the key to increase biodiversity on farmlands that can also lessen the pressure on local forest. Careful agroforestry plantation design will not only increase the multiple ecosystem functions, but can create a buffer zone to support natural habitats, and to reduce human and wildlife conflict, e.g. with Asian elephants. Further research on agroforestry modelling is required to benefits both human and nature.

Keywords: Tree based farming, species diversity, conservation, ecosystem, Asian elephant

Introduction

Biological diversity is often curtailing for functioning of ecosystem and its services (Isbell et al., 2015). Biodiversity successively promotes ecosystem goods and services which include production of raw materials for consumption and production (provisioning services); carbon sequestration, control of pests and diseases, and climate regulation (regulating services); nutrient cycling and crop pollination (supporting services); and spiritual and recreational values (cultural services) (Mori et al., 2017, see Figure 1). However, biodiversity is now under threat mainly due to anthropogenic disturbances, e.g. agricultural expansion, deforestation, and overexploitation of natural resources, which has significant negative impact to ecosystem services and climate (Udawatta et al., 2021; Coelho et al., 2020). Furthermore, biodiversity loss undermines the capacity to create biological materials (biocapacity), and can affect millions of living organisms in which their lives rely on (Zari and Pederson, 2014).

Agroforestry can be an effective tool to preserve species diversity and to improve the ecosystem functions and services due to many reasons: i) it supports natural interactions between various species living in the same area and offers habitat for certain disturbance-tolerant species, ii) it conserves soil from erosion and support purifying water, that prevent habitat degradation and loss, contributing to biodiversity conservation, iii) it increases vegetation structure and variants, that can help with nutrient cycling, soil erosion control, and biodiversity enhancement, without sacrificing farm production, iv) it can function as a habitat corridor for area-sensitive plant and animal species (Kumar, 2016; Udawatta et al., 2019).

Globally, agroforestry accounts for more than one billion hectares or about 43% of agricultural land (Santos et al., 2019). As over two billion hectares of degraded land exist globally, it can give opportunity to rehabilitate some of this land through agroforestry to fulfill the livelihood needs of constantly growing population, while reducing the negative impact to biodiversity and environment (Duffy et al., 2021; Dagar et al., 2020). A well designed agroforestry consists of suitable species can potentially restore the degraded land, and to increase ecosystem functions and biodiversity (Siarudin et al., 2021; Martin et al., 2020; Rahman et al., 2019).

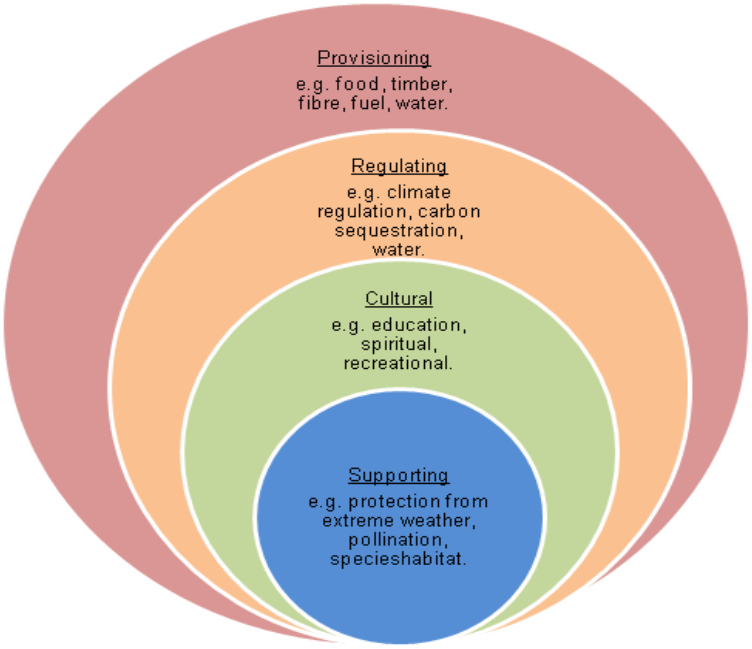


Figure 1. Four types of ecosystem services (adapted from Mori et al., 2017)

Materials and Methods

This chapter is based on a literature review method (using peer-reviewed and grey literature) to assess the role of agroforestry to enhance biodiversity and ecosystem services in Southeast Asian agricultural landscapes. After selecting keywords and phrases, prospective scientific literature was collected from Web of Science, Google Scholar, and Scopus. After removing duplicates, we have selected 42 of the 512 published literature for extensive review following their relevance. A total of five months from June to October 2021 were spent to extract the data.

The selected keywords and search phrases of this study include- ‘agroforestry’ OR ‘agroforest’ OR ‘tree based farming’ OR ‘alley cropping’ OR ‘mix tree crops planting’, ‘agroforestry’ AND ‘biodiversity’ AND ‘Southeast Asia’, ‘agroforest’ AND ‘biodiversity’ AND ‘Southeast Asia’, ‘tree based farming’ AND ‘biodiversity’ AND ‘Southeast Asia’, ‘agroforestry’ AND ‘ecosystem services’ AND ‘Southeast Asia’, ‘agroforest’ AND ‘ecosystem services’ AND ‘Southeast Asia’, ‘tree based farming’ AND ‘ecosystem services’ AND ‘Southeast Asia’, ‘agroforestry’ OR ‘agroforest’ OR ‘tree based farming’ OR ‘alley cropping’ OR ‘mix tree crops planting’ AND ‘income’, ‘agroforestry’ OR ‘agroforest’ OR ‘tree based farming’ OR ‘alley cropping’ OR ‘mix tree crops planting’ AND ‘species’, ‘agroforestry’ OR ‘agroforest’ OR ‘tree based farming’ OR ‘alley cropping’ OR ‘mix tree crops planting’ AND ‘benefit’, ‘agroforestry’ OR ‘agroforest’ OR ‘tree based farming’ OR ‘alley

cropping' OR 'mix tree crops planting' AND 'habitat', 'elephants'. The inclusion criteria of our literature search was evidence based information of agroforestry systems to enhance biodiversity and ecosystem services in the Southeast Asian agricultural landscapes.

The analysis methods- narrative comparative and narrative qualitative were used to interpret collected information following the objective of this chapter. A careful attention was paid through a process of decontextualization and recontextualization increasing the objectivity of the view of reality.

Result and discussion

Agroforestry and biodiversity conservation

Agroforestry systems have a crucial role to conserve biodiversity and providing ecosystem services. There are at least three major benefits of agroforestry to conserve biodiversity, i.e. i) providing supportive species habitat that tolerate to a certain level of disturbance; ii) maintaining natural habitat existence across the landscapes (in certain conditions, see also Rahman et al., 2017); and iii) creating permeable and more benign 'matrix' of habitats, that can support the integrity of these remnants and the conservation of their populations (Schroth et al., 2004).

Agroforestry systems increase biological diversity on farm lands by cultivating diverse species, that can also provide supporting roles to conserve biodiversity in the natural habitat (e.g. forest) (Rahman et al., 2017; Mcneely and Schroth, 2006). Empirical research has provided evidence that there are a range of species, i.e. trees (timber, fruits, nuts, spices), cereals and oil seed crops, vegetables and herbs, cultivating in the agroforestry systems in Indonesia (Rahman et al., 2016). The jengkol agroforest in Ogan Komering Ilir, South Sumatra (Figure 2), or damar agroforests in Pesisir, Sumatra, or durian agroforests in Jambi and Palembang, or pomelo agroforest in Samut Songkhram, Thailand, are rich in biodiversity (Rahman, 2017; Rahman et al., 2016; Michon, 2005). Furthermore, research conducted in West Java and West Sumatra, Indonesia (Rahman et al., 2017; Murniati et al., 2001), and in Mindañao, the Philippines (Garrity et al., 2002) found the link between increased agroforestry practices and conserving local forest biodiversity by reducing pressure on local forest. This is because, through tree-based climate smart farming, agroforestry can provide potential alternatives of many important forest products (e.g. fruits, vegetables, herbs, spices, firewood, timber and fodder) that are important for local livelihoods (Snelder and Lasco, 2008; Michon, 2005). However, some challenges faced by farmer, i.e. land, labour, and capital,

may determine the capacity of agroforestry to reduce deforestation (Angelsen and Kaimowitz, 2004)

Therefore, with such qualities, agroforestry systems can gain further importance in an international political level in a view of the Convention on Biological Diversity (CBD), which has emphasized resource management through ecosystem approaches, including conservation, equitable sharing and sustainable use of benefits (Mcneely and Schroth, 2006).



Figure 2. Damar agroforest in Pesisir(left), and jengkol agroforest in Ogan Komering Ilir, both in Sumatra (right). Photo © Michon, 2005 (left) and Muhardianto Cahya (right).

Agroforestry and ecosystem services

Agroforestry systems help improving ecosystem functions through enhanced delivery of various services. Table 1 is showing the list of services provided by different agroforestry systems in Southeast Asia.

Enhancing ecosystem services through agroforestry systems can also increase farm income and create jobs for the rural communities (Rahman, 2011). In the Philippines (Cagayan de Oro), cultivating trees (i.e. *Gliricidia sepium*) with fodder grasses helped people to enhance their income from the production of livestock, as well as reduce farm labour from herding (FAO, 2005). In

Central and Eastern Java, Indonesia, creating 'living savings account' through developing tree cultivation on farm lands, supported costs of temporary migration of young people to the cities to generate further family income (Roshetko et al., 2008). Local people also consider agroforestry systems as a crucial mechanism that can diversify farm production, enhance household income, and reduce livelihood related risk (Schuren and Snelder, 2008). Therefore, even agroforestry has lesser capacity in delivering many ecosystem services per land area compared to forests, the value of agroforestry systems remain crucial as the global forest resources are under pressure and human population is expanding (Snelder and Lasco, 2008; Roshetko, 2013).

Table 1. Various ecosystem services provided by agroforestry systems in Southeast Asia

Country/ agroforestry type	Ecosystem services	Reference
Vietnam Homegardens	*Provisioning services* Peanut, rice paddy, hill rice, vegetables, sugarcane, cassava, maize, mango, grapefruit, custard apple, longan *Supporting services* Income generation, nutrition	Hoang et al., 2017
Vietnam Berry + coffee based agroforestry	*Provisioning services* Berry, coffee *Supporting services* Improving soil fertility, reducing soil erosion, enhancing biodiversity	Nguyen et al., 2020
Vietnam Fruit tree based agroforestry	*Provisioning services* Longan, maize, guinea grass, mulato grass *Supporting services* Reducing soil erosion, enhancing soil moisture and fertility, weed control *Cultural services* Women empowerment	Do et al., 2020
Thailand Fruit + rubber based agroforestry	*Provisioning services* Wood, timber, jackfruit, rambutan, coconut, pineapple, banana, vegetables *Supporting services* Diversity of plants, birds, reptiles and butterflies	Warren-Thomas et al., 2019
Malaysia	*Provisioning services* Wood, timber, meat	Musa et al., 2019

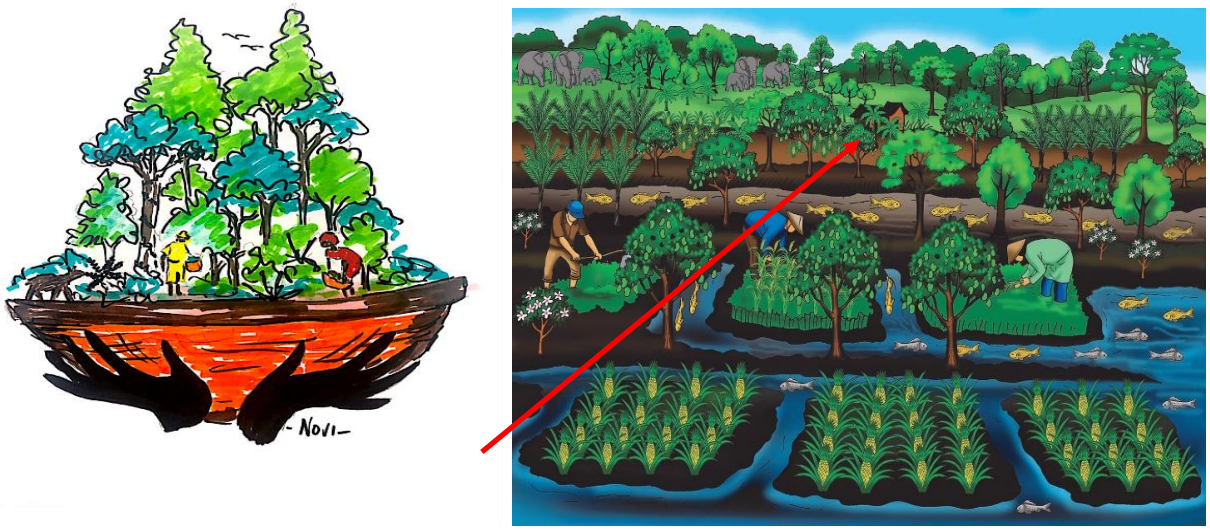
Agrosilvicultural and silvopastoral	*Supporting services* Soil conservation, soil fertility	
Indonesia Cocoa + durian + langsat based agroforestry	*Provisioning services* Cocoa, fruits *Regulating services* Climate regulation *Supporting services* Enhancing biodiversity	Sari et al., 2020
Indonesia Cocoa complex agroforestry (cocoa, fruit tree, sandalwood, bitti, cananga and white teak tree	*Provisioning services* Cocoa, fruits, wood, timber *Regulating services* Carbon storage, water regulation	Sari et al., 2020
Indonesia Rattan + timber tree based agroforestry	*Provisioning services* Food-young juvenile of rattan, timber, fuelwood	McShane and Wright, 2020
Indonesia Rubber + durian + gaharu based agroforestry	*Provisioning services* Rubber, gaharu wood, durian, bamboo *Regulating services* Hydrological function *Supporting services* Soil erosion control, biodiversity	Insusanty et al., 2018
Philippines Cocoa based agroforestry	*Regulating services* Carbon storage	Lasco et al., 2001
Philippines Multistory agroforestry system	*Provisioning services* Coffee, cocoa, mango, durian, lanzones, mangosteen, marang, jackfruit, rambutan *Regulating services* Carbon sequestration, water regulation *Supporting services* Soil erosion control, biodiversity	Palma et al., 2020

Agroforestry for mitigating conflict between human and Asian elephants (Elephas maximus)

Family of Asian elephants roam in Sri Lanka, India, Nepal, Bhutan, Bangladesh, Myanmar, Cambodia, Viet Nam, Laos, China, Malaysia (Malay Peninsula), Sumatra (Indonesia) and Borneo (Malaysia and Indonesia) (Williams et al., 2020). Much of their habitats are in areas with dense human population, and therefore experiencing threats from major anthropogenic land conversions (Williams et al., 2020). Furthermore, elephant habitat fragmentation has caused their population to decline (Williams et al., 2020). Land expansion, including agriculture, has also increased conflict intensity and frequency between human and elephants (Shaffer et al., 2019). Both elephants and humans may receive losses from the conflict (Sampson et al., 2021; Wilson et al., 2013).

Agroforestry is widely practiced in South and Southeast Asia (Kumar et al., 2012), and many of them mimic the complexity of natural forest structure (Young, 2017), that can potentially benefit both human and wildlife (Figure 3). Elephants are notably known as an umbrella species, where their presence is important for ecosystem health (Kuswanda and Barus, 2017). Asian elephants also act as a seed dispersal agent (Campos-Arceiz and Blake, 2011). Tan et al. (2021) found that at least 25 flora families receive benefits from elephants as their disbursement agent. Absence of mammals, particularly the seed dispersal type, such as elephants, could create an empty forest (Redford, 1992).

Land-use change has caused an impact on elephant's movement (Erot et al., 2020), including an increasing frequency of crop raiding in the community land (Anuradha et al., 2019). This is due to the lack of food for elephants in the forests (Yamamoto-Ebina et al., 2016). To prevent crop raiding, many communities plant species which are disliked by elephants, such as chili pepper (Hedges and Gunaryadi, 2010). However, such strategy could potentially cause a negative impact on elephant's mentality and create more conflict (Mumby and Plotnik, 2018).



(a) **(b)**

Figure 3. Agroforestry systems, a) layers of canopies of various species mimicking complex forests ecosystem (© Novi Nugraheni); b) sharing agroforestry land with elephants for their free movement in the buffer zone (© CIFOR)

Therefore, one of the feasible strategies is to combine species with careful plantation design, that will not only include species disliked by elephants but also edible for them, in a community or public lands that the local people are willing to share with elephants (list of potential edible and non-edible species for elephants are provided in the Annex). Further, Nyhus and Tilson (2004) have explored the idea to promote a buffer zone between agricultural land and protected areas, using suitable species in well-designed agroforestry systems that can benefit both human and elephants (Figure 3). Therefore, it can be useful to follow up such idea, not only from ecological but also from social perspective. Further research on the modelling of appropriate agroforestry systems in different landscapes could bring benefits both for human and elephants.

Conclusion

This study explored the potential of agroforestry systems to enhance biodiversity and ecosystem services, particularly in the agricultural landscapes of Southeast Asia. Agroforestry systems can potentially contribute to biodiversity conservation through habitat provision, lower the rates of natural habitat conversion, and form benign and permeable habitat remnants. Cultivating diverse

species in agroforestry systems is the key to increase biodiversity on farmlands. In addition, combining agricultural and forestry species can also lessen the pressure on local forest, since these are the substitute for essential forest products, e.g. fruits, vegetables, herbs, firewood, fodder and timber to local communities. Agroforestry systems help improving the function of ecosystem services in the agricultural landscape. There are various ecosystem services that can be provided by agroforestry systems, e.g. soil fertility and erosion control, climate and water regulation, carbon storage, and social safeguarding. These enhancements can implicate increased income and job opportunities. Furthermore, agroforestry systems have a potential role in mitigating conflict between human and wildlife. However, further studies targeted to identify various agroforestry models will require that can maintain harmony and welfare of the farmers without causing conflict with wildlife habitat.

Acknowledgment

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Annex

Table A1. List of edible plants for Elephant

Family	Species
Alangiaceae	*Alangium javanicum* (Blume) Wangerin [4]
Amaranthaceae	*Amaranthus spinosus* L.[5]
Anacardiaceae	*Pentaspadon motleyi* Hook f., *Spondias dulcis*[3] *Lannea coromandelica* (Houtt) Merr, *Mangifera indica* L., *Spondias pinnata* (L. f.) Kurz[5]
Annonaceae	*Cananga odorata* (Lam) Hook f & Thoms, *Miliusa velutina* (Dunal) Hook f & Thomson [5]
Apocynaceae	*Alstonia pneumatophora* Backer ex Den Berger[1] *Holarrhena antidysenterica* Wall, *Wrightia arborea* (Dennst) Mabb[5]
Araceae	*Colocasia gigantea*[1]
Arecaceae	*Calamus* sp., *Daemonorops angustifolius, dan Salacca conferta*[1] *Licuala* sp., *Arenga* sp.[4] *Calamus areborescens* Griff, *Caryota sp.*[2] *Salacca zalacca* (Gaertn) Voss ex Vilmorin [5]
Asteraceae	*Eupatorium odoratum* L., *Mikania cordata* (Burm F.) B.L. Rob, *Tithonia diversifolia* (Hemsl) A. Gray[1]
Bambucaceae	*Bambusa* spp.[1]
Bignoniaceae	*Heterophragma adenophyllum* (Wall ex G.Don) Seem ex Benth & Hook fil, *Markhamia stipulata* (Wall) Seem[5]
Bombacaceae	*Durio zibethinus* L.[1]
Boraginaceae	*Cordia dichotoma* G.Forst., *Cordia grandis* Roxb[5]
Burseraceae	*Santiria laevigata, Dacryodes rostrata* (Blume) H.J.Lam [1]
Burseraceae	*Garuga pinnata* Roxb[5]
Caesalpinaceae	*Bauhinia malabarica* Roxb, *Bauhinia scandens* L., *Cassia fistula* L.[5]
Callophylaceae	*Calophyllum* sp.[3]
Combretaceae	*Terminalia bellirica* (Gaertn) roxb (Bahera)[5]
Convolvulaceae	*Merremia hederacea* (Burm. f.) Hallier f., *Merremia vitifolia* (Burm.f.) Hallier f.[5]
Costaceae	*Costus speciosus* (J.Koenig) Sm[4] *Costus speciosus* Sm[5]
Cyperaceae	*Cyperus rotundus* L., *Cyperus aromaticum*[2] *Cyperus* sp., *Cyperaceae* sp.[5]

Cycadaceae	*Cycas siamensis* Miq[5]
Davalliaceae,	*Nephrolepis exaltata*[1]
Dilleniaceae	*Dillenia excelsa*[1] *Dillenia arbiflos*[3] *Dillenia excelsa* (Jack) Gilg[4] *Dillenia indica* L., *Dillenia parviflora* Griff[5]
Dipterocarpaceae	*Shorea* sp*., Hopea dryobalanoides* Miq[1]
Euphorbiaceae	*Macaranga javanica*[2] *Mallotus paniculatus, Macaranga pruinosa, Macaranga gigantea, Macaranga tanarius, Aporosa mycrocalyx*[3] *Mallotus muticus* (Müll. Arg) Airy Shaw[4] *Croton oblongifolius* Roxb*, Mallotus cochinchinensis* Lour[5]
Fabaceae	*Pueraria phaseoloides*[1] *Intsia bijuga*[3] *Butea superb* Roxb*, Dalbergia oliveri* Gamble ex Prain*, Dalbergia ovata* Graham ex Benth, *Dalbergia volubilis* Roxb*, Millettia extensa* (Benth) Baker*, Mucuna pruriens* (L.) DC[5]
Flacourtiaceae	*Flacourtia ramontchi* L'Herit[5]
Gleicbeniaceae	*Gleichenia linearis* (Burm f.) C.B. Clarke[1]
Guttiferae	*Garcinia mangostana* L.*, Garcinia parvifolia* (Miq) Miq[1]
Hernandiaceae	*Hernandia ovigera* L.[1]
Icacenaceae	*Stemonurus scorpioides* Becc.[3]
Lauraceae	*Litsea* sp.[1]
Lecythidaceae	*Careya arborea* Roxb[5]
Linaceae	*Ixonanthes icosandra* Jack [3]
Lythraceae	*Lagerstroemia tomentosa* C.Presl[5]
Malvaceae	*Ceiba pentandra* (L.) Gaertn[1]
Marantaceae	*Donax canniformis* (G. Forst) K.Schum[4]
Marattiaceae	*Angiopteris evecta* (G.Forst) Hoffm[1]
Melastomaceae	*Melastoma malabathricum* L.[1] *Memecylon* sp.[4]
Meliaceae	*Cedrela serrata* Royle[5]
Menispermaceae	*Tinospora nudiflora* (Griff) Kurz [5]
Mimosaceae	*Albizzia falkata, Mimmosa pudica* L., *Parkia speciosa* Hassk[1] *Pithecellobium dulce* (Roxb) Benth[3]

	Acacia concinna (Willd) DC., *Acacia megaladena* Desv, *Acacia pennata* (L.) Wild, *Albizzia chinensis* (Osbeck) Merr, *Entada pursaetha* DC., *Neptunia* sp., *Samanea saman* (Jacq) Merr, *Xylia xylocarpa* (Roxb) Taub.[5]
Moraceae	*Artocarpus heterophyllus* Lam, *Artocarpus kemando* Miq, *Artocarpus elasticus* Reinw ex Blume[1] *Ficus benjamina*[3] *Antiaris toxicaria* (Pers) Lesch, *Ficus auriculata* Lour, *Ficus cunia* Buch Ham ex Roxb, *Ficus glomerata* Roxb, *Streblus asper* Lour[5]
Musaceae	*Musa laterita* E. E. Cheesman[5]
Myrtaceae	*Syzygium* sp.[4]
Oleaceae	*Jasminum multiflorum* (Burm.f.) Andrews[5]
Onagraceae	*Ludwigia adscendens* (L.) H. Hara[5]
Rutaceae	*Aegle marmelos* L. Corrêa [5]
Pandanaceae	*Pandanus* sp., *Pandanus terrestris* Warb[1]
Phyllanthaceae	*Bridelia stipularis* (L.) Blume[4]
Poaceae	*Ichnanthus vicinus* (F.M.Bailey) Merr, *Imperata cylindrica, Setaria geniculata, Paspalum conjungatum, Digitaria ciliaris* (Retz) Koeler, *Cynodon dactylon* (L.) Pers., *Ottochloa nodosa* (Kunth) Dandy, *Hymenachne amplexicaulis*[1] *Chrysopogon aciculatus* (Retz) Trin, *Panicum repens* L., *Imperata cylindrica* (L.) Raeusch[2] *Paspalum conjugatum*[3] *Phragmites karka* (Retz) Trin ex Steud, *Dinochloa scabrida* S.Dransf[4] *Bambusa bambos* (L.) Voss, *Bambusa burmanica* Gamble, *Bambusa polymorpha* Munro, *Cephalostachyum pergracile* Munro, *Eragrostis japonica* (Thunb) Trin, *Oryza sativa* L., *Phragmites vallatoria* (L.) Veldcamp, *Themeda intermedia* (Hack) Bor, *Thysanolaena maxima* (Roxb) Kuntze[5]
Polygalaceae	*Irvingia malayana* Oliv ex A.W.Benn[3]
Rubiaceae	*Coffea canephora*[3] *Gardenia elata* Ridl[4] *Gardenia turgida* Roxb, *Mitragina rotundifolia* (Roxb) Kuntze, *Morinda angustifolia* Roxb., *Paederia foetida* L.[5]
Salicaceae	*Scolopia spinosa* (Roxb) Warb[1]
Sapindaceae	*Pometia pinnata* J.R.Forst & G.Forst, *Nephelium lapaceum*[1] *Nephelium cuspidatum* var robustum[3] *Lepisanthes fruticosa* (Roxb) Leenh[4]

Sapindaceae	*Mischocarpus pentapetalus* (Roxb) Radlk[5]
Sapotaceae	*Palaquium burckii* H.J.Lam [3]
Smilaceae	*Smilax macrophylla* Roxb[5]
Sterculiaceae	*Heritiera fomes* Buch-Ham[1]
Theaceae	*Archboldiodendron calosericeum*[1]
Thymeleaceae	*Aquilaria* sp.[1]
Tiliaceae	*Grewia hirsuta* Vahl, *Grewia humilis* Wall ex G. Don[5]
Verbenaceae	*Vitex pubescens, Peronema canescens*[1] *Gmelina arborea* Roxb ex Sm., *Tectona grandis* L.f., *Vitex leucoxylon* L.f.[5]
Zingeberaceae	*Achasma megalocheilas*[1] *Alpinia aquatica* (Retz) Roscoe, *Nicolaia speciosa* (Blume) Horan, *Curcuma* sp.[3] *Alpinia ligulata* K.Schum[4] *Amomum corynostachyum* Wall[5]

[1]Syarifuddin H., 2008; [2]Hamdani et al., 2018; [3]Wardana et al., 2017; [4]English et al, 2014; [5]Campos-Arceiz et al., 2008.

Table A2. List of non-edible plants for Elephant

Family	Species
Arecaceae	*Caryota mitis* Lour., *Arenga* sp., *Pinanga sp.*[2]
Euphorbiaceae	*Aleurites moluccana* (L.) Willd[1]
Lamiaceae	*Pogostemon cablin* Benth[1]
Malvaceae	*Theobroma cocoa*[1]
Rubiaceae	*Coffea arabica*[1]
Solanaceae	*Capsicum frutescens*[1]

[1]Berliani et al., 2018; [2]Suba et al., 2020.