Ecosystem services of rubber agroforestry system: A review

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Abstract
Mono rubber plantation is generally known to be a source of high economic income. However, various impacts on ecology remain controversy. In order to balance between the economic and environmental aspects, rubber agroforestry system (RAS), a system that rubbers are planted together with different kinds of tress, is seen to be one of the environmentally friendly solution. The objective of the study was achieved through a literature review covering researches about RAS ecosystem services worldwide but most researches came from Indonesia and Thailand. The results shows that RAS provides ecosystem services covering four types: provisioning services (sources of natural rubber, sources of food and sources of wood), regulating services (carbon stock, soil erosion control and water balance), supporting services (biodiversity) and cultural services (education). These results are very useful for environmental sustainability that can also secure the economic benefit of RAS. More studies on appropriate model of RAS are still needed to be carried out to maximize both ecological and economic services for farmers and society.

Keywords: Agroforestry, Ecosystem services, Rubber, Rubber agroforestry systems

Introduction

The development that focuses on economic growth and ignores social and environmental sustainability is reflected in land use changes, particularly from forest area to rubber plantations in Southeast Asia. It is the region which is considered to be the world's largest rubber plantation the area is still expanding continuously. (Food and Agriculture Organization of the United Nations: FAO, 2014).

The increase of rubber plantation area, which mostly is mono-cultural, has raised serious concerns about the reduction of ecosystem services (ES). Ecosystem services are benefits from the ecosystem that are very significant to human well-being, because ES provides both direct and indirect benefits, such as security, basic material for good life, health, good social relations and freedom of choice and action (The economics of Ecosystems and Biodiversity: TEEB, n.d.).Rubber Agroforestry System (RAS) is a type of rubber plantations where its structure is similar to the secondary forest (Wulan, Budidarsono and Joshi, 2006 and Beukema, Danielsen, Vincent, Hardiwinoto and Van Andel, 2007), which is believed to provide various ecological services for human. This study thus aims to examine the four major ES based on the concept of Millennium Ecosystem Assessment: MA (2005), which are provisioning service, regulating service, supporting service and cultural service as follows:

Methodology

This study was conducted through a literature survey on previous and current researches on RAS relating to ES. The information collected through the survey was then organized, categorized and analyzed to provide results as shown in the following section.

Results

The result of a literature review about RAS ecosystem services showed that RAS can provide ES covering provisioning service, regulating service, supporting service and cultural service as follows:

Provisioning services

Provisioning services are services of basic material production. Most provisioning services of RAS are mostly the productions from plants grown in the plantation, such as rubber tree products and companion plant products. The literature review showed that RAS provides ES which includes sources of natural rubber, food, and sources of wood as follows:

Sources of natural rubber

Rubber is one of the important basic materials for various processed products to facilitate convenience in human life such as tire, boot and gloves. RAS provides natural rubbers in both latex and natural rubber sheet for selling (Parham, 2000; Joshi *et al.,* 2002; Wulan *et al.,* 2006; Manivong and Cramb, 2007; Wibawa, Joshi, Van Noordwijk and Penot, 2008; Sarakawee, 2010; Kumar and Nair, 2011; Kheowvongsri, 2012 and Kittitonkul, 2014). Furthermore, the high density of plants in RAS increases

humidity resultingin high latex productions in drought period (Jongrungrot and Thungwa, 2013).

Sources of food

The presence of edible food in RAS also enhances food security for the farmers. Their food products surplus can be traded to generate more incomes (Kheowvongsri, 2012) or to share with neighbours in the community. The literature showed that there were three types of food plants: vegetables (Rubber Authority of Thailand, n.d; Puegwaroon and Pahana, 1989; Kheowvongsri, 2002; Wulan *et al.,* 2006 and Kittitonkul *et al.,* 2014), fruits (Kongseepan, Pooranatam and Choogamnurd, 1989; Pahana and Puegwaroon, 1989; Sangragsawoong 1989; Zhaohua, Maoyi and Sastry, 1991; Wibawa, 2007; Sarakawee, 2010 and Kittitonkul *et al.,* 2014) and medicinal herbs.(Kheowvongsri, 2002 and Jongrungrot and Thungwa, 2013) as shown in Table 1.

Table 1 Example of vegetables, fruits and medicinal herbs in RAS.

type of plant	**common name**	**scientific name**
Vegetables	Baegu	*Gnetum gnemon* (Linn.) var. tenerumMarkgr.
	Rough Giant Bamboo	*Dendrocalamus asper* (Schultes f.) Backer ex Heyne.
	Climbing Fern,	Stenochlaena palustris (Burm. f.) Bedd.
	Vegetable fern	*Diplazium esculentum* (Retz.) Sw.
	Torch Ginger	*Etlingera elatior* (Jack) R.M. Smith.
Fruits	Wollongong	*Lansium domesticum* Corr
	Salakpondoh	*Salacca zalacca*(Gaertn.) Voss
	Mangosteen	*Garcinia mangostana* Linn.
	Janpuling	*Baccaurea kunstleri* King ex Gage.
	Tamarind	*Tamarindus indica*L.
	Jack fruit	*Artocarpus heterophyllus Lam.*
	Durian	*Durio zibethinus* Murray.
Medicinal herbs	Wild Pepper	*Piper sarmentosum* Roxb.
	False citronella	*Cymbopogo nnardus* (L.) Rendle.
	Kaempfer	*Boesenbergia rotunda* (L.) Mansf.
	Laurel clock vine	*Thumbergia laurifolia*Lindl.

Sources of wood

Besides the value of wood rubber (Manivong and Cramb, 2007), other companion woody trees in RAS can also provide this wood value. (Zhaohua *et al.,* 1991; Wibawa*,* Hendratno and Van Noordwijk,2005; Wulan *et al.,* 2006; Wibawa *et al.,* 2008 and Kumar and Nair, 2011). The review of literatures found these types of plants in RAS: basketry (Booranatam *et al.,* 1998 and Rattanawirakool, 1998), and furniture and building (Jantooma, Jantooma, Pajchimsawas and Pechying, 2011 and Kittitonkul *et al.,* 2014) as detailed in Table 2.

Table 2 Example of plants used for basketry plant, furniture and building in RAS

type of plant	common name	scientific name
Basketry	WaiNyair	*Calamus latifolius* Roxb.
	WaiTakatong	*Calamus caesius*Blume.
Furniture and building	Teak	*Tectona grandis* L.F.
	White Meranti	*Shorea roxburghii* G.Don
	Yang	*Dipterocarpus alatus* Roxb.
	Brown Salwood	*Acacia mangium* Willd.
	Iron Wood, Thingan	*Hopea odorata* Roxb.
	Black Wood, Rose Wood	*Dalbergia cochinchinensis* Pierra.

Regulating services

Regulating service is the service that regulates ecosystem processes. Many researches revealed that RAS offers this service, which includes carbon sequestration, soil erosion control and water balance:

Carbon sequestration

Due to the impact of climate change during the past few years, carbon sequestration has become a main issue in dealing with climatic changes because it involves removal and storage of carbon from the atmosphere. This owes to the fact that RAS is an area containing the variety of plant sizes and numbers, which has high potential for absorbing carbon from atmosphere and storing it indifferent parts of the plants (Joshi *et al.,* 2002; Wulan *et al.,* 2006; Wibawa, Joshi, Van Noordwijk and Penot. 2007; Zhang, Fu, Feng and Zou, 2007; Bumrungsri *et al.,* 2011; Kumar and Nair, 2011 and Kittitonkul *et al.,* 2014).

Soil conservation

Loss of soil nutrients is a serious problem affecting agricultural products. The complexity of RAS canopy helps reduce run-off (Witthawatchutikul, 1993). The complexity of RAS root system also helps adhere soil surface (Wibawa *et al.,* 2007 and Kittitonkul *et al.,* 2014). Both abilities can be used to reduce nutrient loss. In addition, high litter falls in RAS help increase nutrients in soil (Wibawa *et al.,* 2007 and Bumrungsri *et al.,* 2011) leading to lower amount of fertilizer used.

Water balance

The problem of water balance including water shortage or flood has become a critical impact on human life. High plant density of RAS results in reduction of evaporation rate (Phuphak, 2006 and Jongrungrot and Thungwa, 2013) and the complex roots system in RAS provides an appropriate combination of soil that increases the infiltration rate (Phuphak, 2006 and Witthawatchutikul, 1993).

Supporting services

Supporting services are necessary for the production of other ES. Several researches suggested the benefit of RAS as a source of biodiversity, as shown in the following:

Biodiversity

Currently, the decrease of forest area and the increase of mono-cultural agricultural areas have resulted in reduction of biodiversity (plants and animals). RAS is an agricultural system that increases biodiversity (Joshi *et al.,* 2002; Wulan *et al.,* 2006 and Kumar and Nair, 2011) owing the combination of planting variety of trees mixed with rubber (Agduma *et al.,* 2011 and Kheowvongsri, 2012). This system increase habitat complexity for different animals. From literature reviews, three types of animal are found: small mammal (Sribandit*,* Agduma and Jantrarotai, 2010), birds and bats (Bumrungsri *et al.,* 2011), and amphibian and reptile (Hangam, Duengkae and Wacharinrat, 2006) as detailed in Table 3.

Table 3 Example of small mammals, birds, bats, amphibians, and reptiles in RAS

type of animal	**common name**	**scientific name**
Small mammals	Savile's Bandicoot Rat	*Bandicota savilei*
	Rajah Spiny Rat	*Maxomys rajah*
	Finlayson's Squirrel	*Callosciurus finlaysonii*
	Gray-bellied Squirrel	*Callosciurus caniceps*
Birds	Stripe-throated Bulbul	*Pycnonotus finlaysoni*
	Puff-throated Babbler	*Pellorneum ruficeps*
	Olive-backed Sunbird	*Nectarinia jugularis*
Bats	Blyth's Horseshoe Bat	*Rhinolophus lepidus*
	Lesser Bicoloured Leaf-nosed Bat	*Hipposideros atrox*
	Lesser Dog-faced Fruit Bat,	*Cynopterus brachyotis*
Amphibian	Banded Bullfrog	*Kaloula pulchra*
	Marten's Puddle Frog	*Occidozyga martensii*
	InornateFroglet	*Micryletta inornata*
Reptile	Striped striped skink	*Lipinia vittigera*
	Bengal monitor	*Varanus bengalensis*
	Stream terrapin	*Cyclemys dentate*

Cultural service

Cultural services are the services that provide abstract benefits which affect spiritual enrichment, cognitive development, reflection, recreation, and aesthetic experiences. However, most reviewed studies reported only RAS cultural services in term of education only. For the past few years, RAS had not only become to research area for researchers but also for agroforestry farmers who are interested in RAS too (Jongrungrot and Thungwa, 2013 and Kittitonkul *et al.,* 2014).

Discussion

This objective of this study was to examine RAS ecosystem service through a literature review about RAS research. The results show that RAS provides ecosystem services covering four main ecosystem services type based on the concept of MA (2005): provisioning services (sources of natural rubber, sources of food and sources

of wood),regulating services (carbon stock, soil erosion control and water balance), supporting services (biodiversity) and cultural services (education). These various of ES providing in RAS are generated from numerous interactions occurring of plants and animals in complex systems (Harrison *et al.,* 2014).

The result of this study accordance with the result of Jose (2009) which explains that general agroforestry can provide ES that covering four main ecosystem service types. The comparison between ES of RAS and general agroforestry shows that RAS is distinguish by the fact that it provides ES in term of natural rubber and biodiversity is which is likely to make RAS able to provide other ES not yet covered in this study.

Conclusions

This study is a literature review of RAS ecosystem services. The results showed that RAS provides major ES based on the concept of MA (2005), which are provisioning services, regulating services, supporting services, and cultural services. However, many ecosystem services are not yet reported due to the limitation of some information that are still needed to be studied, such as oxygen production, temperature control, flood control, etc. Therefore, there are still gaps of researches needed to be done in the future in this area.

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