Ecosystem services-based mangrove management strategies in Indonesia: a review

[1,2]Achmad Sofian, [1,4]Cecep Kusmana, [3]Akhmad Fauzi, [4]Omo Rusdiana

[1] Study Program of Natural Resources and Environmental Management, Graduate School of Bogor Agricultural University (IPB), Bogor, Indonesia; [2] KKD-BP Fisheries Social Economic, Marine and Fisheries Polytechnic of Sorong, Sorong, West Papua, Indonesia; [3] Department of Resources and Environmental Economics, Faculty of Economics and Management, Bogor Agricultural University (IPB), Bogor, Indonesia; [4] Department of Silviculture, Faculty of Forestry, Bogor Agricultural University (IPB), Bogor, Indonesia. Corresponding author: A. Sofian, achmad.sofian@kkp.go.id

Abstract. Mangrove ecosystems have strategic benefits and complex management. Management of mangrove ecosystems also faces pressures and challenges to maintain them in sustainable condition. This study was aimed to review various literatures on mangrove management, particularly related to ecosystem services, and to find contribution opportunities in this field of research. Ecosystem service approach is more developed in natural resource management and becomes an instrument connecting ecosystem functions with human wellbeing. Analysis results showed that ecosystem services are an important part of mangrove management. Mangrove provides many ecosystem services and has an important role in both the number and the type of ecosystem services. There are several research opportunities which can be conducted namely ecosystem service condition analysis, socio-economic analysis and valuation, system structure, and future prospective strategies. These aspects are certainly a challenge in developing a dynamic and complex mangrove ecosystem management strategy in Indonesia as an effort to achieve sustainable management objectives.

Key Words: ecosystem services, management, valuation, mangrove, socio-economic.

Introduction. Ecosystem service is one of the great interest topics for many scientists and has been on the rise over the past decade (Mcdonough et al 2017). Ecosystem services are the benefits that humans derive directly or indirectly from ecosystem functions (Costanza et al 1997; Häyhä & Franzese 2014). Ecosystem service is defined as benefits of ecosystems for human wellbeing (Millennium Ecosystem Assessment 2005; TEEB 2010; Elliff & Kikuchi 2015). The concept of ecosystem services is very interesting to study for some reasons: (1) it may assist describing the connection and dependence of humans on nature; and (2) describes how human impacts on ecosystems alter the capacity in providing services, so appropriate policies can be developed (Haines-Young & Potschin 2013). Ecosystem is a functional unit of the biological community of animals, plants, microorganisms and non-biological environments that are complex and highly dynamic, and interact with each other (Millennium Ecosystem Assessment 2003). The mangrove ecosystem is one of the ecosystems that have various benefits of service for the society welfare but faces the pressures.

Indonesia is an archipelago country with more than 17,504 islands and about 95,181 km coastline (Kusmana & Sukristijiono 2016). Indonesia has a 3.1-3.7 million hectares mangrove forest area or more than 20% of world's mangrove forests with high species diversity (Giri et al 2011; Kusmana 2015b; Ilman et al 2016). Beside that, Potential area to be planted with mangrove species is around 7.8 million hectares (Kusmana 2015b). Indonesia's mangrove has a specific function because it lies between the terrestrial and marine ecosystems, and support various types of human needs, especially for local communities in mangrove forests and surrounding areas (Kusmana 2015b; Kusmana & Sukristijiono 2016). This facts show that the potential of mangrove ecosystem in Indonesia is quite large at this time.

Mangrove forests contribute in providing ecosystem services and supporting the livelihoods of coastal communities around the world (Polidoro et al 2010). Mangrove ecosystems have an important role in the socio-economic of communities, even for millions of people in the tropics and subtropics (Atkinson et al 2016). The important role of mangrove ecosystems are providing ecological and biophysical services, and providing a variety of important ecosystem products and services that are critical to the livelihoods of nearby communities (Barbier et al 2011; Malik et al 2015a; Orchard et al 2016). In addition, mangrove ecosystems also serve ecological functions in providing ecosystem services, nutrient cycles, soil formation, timber production, fish spawning, ecotourism and carbon storage (C) (Murdiyarso et al 2015) including economic activities such as providing timber and leaves as raw medicine materials (Sonjaya 2007).

The mangrove ecosystem is one of the most endangered ecosystems in the world. It experiences encroachment pressure and land degradation continuously, mainly driven by human activities (Ghosh et al 2015). Ilman et al (2016) studied about the drivers of the loss of Indonesia's mangrove forests through historical image analysis and estimated the decline of mangrove forest area in all regions of Indonesia by 22 percent. The largest percentage was occurred in Java Island by 75 percent. Pressures on mangrove ecosystems and more widespreading of degraded land have potential in affecting ecosystem services as well. Ecosystem services are also attached to the mangrove ecosystem so that it will also affect the management policy. Therefore, the mangrove ecosystem need to be managed to provide benefits for current and future generations.

Mangrove and conservation management policies are emerging worldwide in line with the increasing appreciation of the benefit of mangrove (Carter et al 2015). Mangrove ecosystem as described by Kusmana (2015a) requires a management because mangroves have the benefit of providing ecosystem goods and services, but also experiences the destruction. The management needs to be integrated and sustained. Management of sustainable mangrove ecosystems is an integration of all efforts to realize the sustainability of mangrove ecosystem functions for the community wellbeing (Presidential Regulation of the Republic of Indonesia No. 73 of 2012). Sustainable management is in accordance with the development orientation that pays attention to social, ecological and economic sustainability (Turner et al 2016). Indicators used in the management of mangrove ecosystems were ecology, economy, social and institutional (Iftekhar & Islam 2004; KKMTN 2013; Schmitt & Duke 2015; Kusmana 2015a; Orchard et al 2016).

Ecosystem services are important aspect in ecological and socio-economic studies of mangrove management. The linkage of ecosystem services and mangrove management is very closely related to the function of mangrove ecosystem to human wellbeing. Therefore, mangrove ecosystem services must be an important aspect in the management. This study was aimed to review various literatures on mangrove management, particularly related to ecosystem services and to find contribution opportunities in this field of research.

This review used a literature study concerning "mangrove management" and "ecosystem services" in the title, abstract, keywords, and content. A review of the literature to better understand current conditions in the development of research fields, both theme, methods and other combinations are associated with ecosystem services and mangrove management. The study was conducted through defining stages and topics, searching and selecting studies, analyzing and synthesizing. The defining stage is done by explaining the ecosystem services and mangrove management, while the topics were focused on six studies after introduction, those are: (1) the concept of ecosystem services, (2) mangrove ecosystem services, (3) the value of mangrove ecosystem services, (4) mangrove ecosystem management in Indonesia, (5) study, analysis, and strategy of mangrove services management, and (6) research prospect of ecosystem service management. Scientific publications which become reference are derived from the scopus data base (https://www.scopus.com), google scholar (https://scholar.google.com/), garuda portal (http://id.portalgaruda.org/) as well as various other literatures such as reports, and supporting books.

Concept of ecosystem services. Ecosystem provides many services to the human as part of the ecosystem itself. Changes that occur in the ecosystem will certainly affect the existence of ecosystem services and ultimately on human wellbeing (Millennium Ecosystem Assessment 2003). According to the literature reviews, ecosystem service approach is connecting between environmental and socio-economic interests (De Groot et al 2010a; Haines-Young & Potschin 2010). The concept of ecosystem services has undergone many developments and has been used in natural resource assessments since the late 1970s and then continued in the 1990s with the main focus on ecosystem services in the literature (Gómez-Baggethun et al 2010). A study of ecosystem services was conducted among others by Costanza et al (1997) who first valued ecosystem services and natural resource capital globally, and the study was further expanded, particularly since the publication of the concept of ecosystem services carried out by Millennium Ecosystem Assessment in 2003.

The concept of ecosystem services is very important in connecting ecosystem functions with human welfare (Fauzi & Anna 2005). The classification of ecosystem services used should refer to the importance characteristics of the ecosystem and in the context of decisions for how ecosystem services will be used (Fisher et al 2009). Understanding the rules of ecosystem services and functions (provision) to human well-being is also essential in obtaining identification and targets of seeking the natural capital of a system and complementing the requirements of sustainable development (De Jonge et al 2012). The classification of ecosystem services used by the Common International Classification of Ecosystem Services (CICES) has three types of ecosystem services (Haines-Young & Potschin 2013) comprises provisioning categories such as biomass and water, regulating and maintenance such as pest and disease control, and cultural such as physical interactions, intellectual and spiritual with the ecosystem.

Classification of ecosystem services is useful to clarify the understanding in identification of services according to the studied ecosystem. Classification of ecosystem services of Millennium Ecosystem Assessment is widely used (Fisher et al 2009). The classification of CICES specifically focuses on ecosystem outputs that directly contribute to public wellbeing and aims for economic assessment (Haines-Young & Potschin 2013). The use of classification needs to be adapted according to the objectives of the study, particularly if it is related to economic valuations to avoid recurring calculations (Elliff & Kikuchi 2015). A good understanding of ecosystem services will assist in gaining a picture of ecosystem connection with community wellbeing.

Various appropriate efforts in mangrove ecosystem management strategies should be continued. According to Walters et al (2008), improper anticipatory efforts in resource management and land use against the pressures faced may threaten the existence of ecosystems and humans who depend on it. Complexity of the mangrove ecosystem also requires cooperation and participation of all government levels, in addition to policies and programs which still become a key to sustainability of mangrove management and coastal ecosystems (Carter et al 2015). Knowledge and attention to the mangrove ecosystems including changes in ecosystem management is an important basis in further management. Ecosystem service becomes one of the tools to increase the knowledge (Luque et al 2017) and use it in mangrove ecosystem management strategy.

Mangrove ecosystem services. Mangrove has many important ecosystem services and values (Salem & Mercer 2012; Schmitt & Duke 2015). The role of mangrove ecosystem is very important at least on two things (Kusmana & Purwanegara 2015):

1. approximately 75 to 90% of all marine fish species, a whole or a part of its life cycle depends on estuarine habitat, and its productivity depends largely on the production of organic materials from mangrove and seagrass plants;

2. mangrove is one of the main ecosystem types in maintaining coastal environmental quality where approximately 50% of the population in the world and 2/3 of the world's major cities are living in coastal areas.

Indicators of mangrove ecosystem services based on literature reviews vary considerably from provisional, regulatory and maintenance, and cultural. Indonesian people have been traditionally since long time ago utilize mangrove ecosystem services (provisioning) such as for firewood, charcoal, medicines, dye and other uses such as the use of aquatic fauna to support daily life (Kusmana & Sukristijiono 2016). Ecosystem services provided by the mangrove ecosystem are summarized in Table 1.

Table 1

Indicators of mangrove ecosystem services

No	*Category*	*Indicator*	*Description*	*Source*
1	Provisioning	Fishery (food)	Providing fisheries as a source of food	Harahab (2009); Macintosh et al (2010); Kuenzer et al (2011); Uddin et al (2013); Mukherjee et al (2014); Malik et al (2015b); Vo et al (2015).
		Aquaculture	Cultivation of brackish fisheries such as shrimp and milkfish ponds	Macintosh et al (2010); Kuenzer et al (2011); Mukherjee et al (2014); Malik et al (2015b); Sina et al (2017).
		Honey	A sweet fluid collected by insect	Macintosh et al (2010); Kuenzer et al (2011); Uddin et al (2013); Mukherjee et al (2014).
		Medicines	Traditional medicines	Macintosh et al (2010); Kuenzer et al (2011); Mukherjee et al (2014).
		Feedstock	Mangrove as raw material	Mukherjee et al (2014).
		Energy source	Wood fuel is used for daily activities such as making charcoal, cooking food, burning bricks	Macintosh et al (2010); Kuenzer et al (2011); Uddin et al (2013); Mukherjee et al (2014); Malik et al (2015b).
		Timber	Wood for building and carpentry	Macintosh et al (2010); Uddin et al (2013); Mukherjee et al (2014); Vo et al (2015); Sina et al (2017).
		Tannin	Phenolic substances derived from plants used for tannery	Kuenzer et al (2011).
2	Regulation and maintenance	Water bioremediation	Maintaining water quality	Walters et al (2008); Barbier et al (2011); Mukherjee et al (2014).
		Reducing emission	The presence of mangrove reduces emissions	Mukherjee et al (2014).
		Environmental risk indicator	Mangrove as risk indicator	Mukherjee et al (2014).
		Protecting from sedimentation	Stabilization of land by restraining sediment	Macintosh et al (2010); Mukherjee et al (2014).
		Protecting from sea water intrusion	Mangrove can protect from intrusion	Mukherjee et al (2014); Malik et al (2015b).
		Coastal protection	Protecting the coastal from the onslaught of waves, winds and floods	Macintosh et al (2010); Barbier et al (2011); Kuenzer et al (2011); Mukherjee et al (2014); Malik et al (2015b); Barbier (2016).
		Fish nursery	Mangrove as nursery ground for fish	Mukherjee et al (2014); Malik et al (2015b).
		Carbon sink	Absorbing carbon dioxide	Walters et al (2008); Macintosh et al (2010); Mukherjee et al (2014); Malik et al (2015b); Vo et al (2015) .
		Reducing coast and soil erosion	Reduction of coast and soil erosion	Macintosh et al (2010); Barbier et al (2011); Vo et al (2015).
		Climate regulator	an important role on climate change	Macintosh et al (2010).
3	Cultural	Ecotourism and recreation	Providing unique and aesthetic values, and as a suitable habitat for flora and fauna	Macintosh et al (2010); Barbier et al (2011); Kuenzer et al (2011); Uddin et al (2013); Mukherjee et al (2014).
		Aesthetic value	The value of appreciation of the beauty of nature	Uddin et al (2013); Mukherjee et al (2014).
		Spiritual appreciation	Appreciation related to belief	Macintosh et al (2010); Kuenzer et al (2011); Uddin et al (2013).

Ecosystem services are identified in accordance with the presence of mangrove ecosystems in an area and need to be valued in monetary terms (money) so that they can be clearly calculated for their economic contribution and compared to the market of goods and services (Häyhä & Franzese 2014). The value of ecosystem services can not be ignored, for example the cultural are essential in understanding how humans use and assess nature, but are often ignored in forest assessments due to limitations in measurement and mapping (Luque et al 2017). The values can clarify and strengthen the position of ecosystem services into consideration in the formulation of management strategies.

Value of mangrove ecosystem services. Value of mangrove ecosystem service describes the relative price, usefulness, and importance of a thing (Moore et al 2017). Although assessment of the ecosystem and its services is still a debate (Häyhä & Franzese 2014), economic valuation plays an important role in the assessment of natural resources to assist in decision-making and sustainable management processes (Zhang & Lu 2010; Fauzi 2014; Vo et al 2015). A study conducted by Moore et al (2017) using the ecosystem services natural resource approach (Ecosystem Services-Natural Resources Management) stated that valuation will assist decision makers in evaluating and communicating overall benefits and trade-offs to stakeholders. In assessing forest ecosystem services, the capacity of ecosystem services are determined by the long-term temporal dynamic (Luque et al 2017).

Assessment of goods and services of mangrove ecosystems is needed because mangrove provides many benefits and plays important roles for better conservation (Muraleedharan et al 2009). Economic valuation approach of mangrove resources will help policy makers and decision makers to know the value of mangrove ecosystem comprehensively (Ilman et al 2011). The economic valuation of goods and services of mangrove ecosystems is able to show the benefits of a good mangrove ecosystem for the community and this is an important reason to manage and protect the mangroves (Schmitt & Duke 2015). Understanding of the value and services of mangrove ecosystems is becoming increasingly important for local, national, and global policies and decisions (Kairo et al 2001; Vo et al 2015).

Mangrove provides real ecosystem services, but is not fully supported by optimal conservation and protection. Conservation as a biodiversity protection often faces inadequate economic resources and thus requires the support of integrative instruments and incorporates economic goals and conservation impacts (Luque et al 2017). Although not all the benefits of ecosystems can be expressed monetarily, some analyzes can still contribute to the various decision options (De Jonge et al 2012).

Studies of mangrove ecosystem valuation in Indonesia have been carried out such as Malik et al (2015b) which estimates that annual mangrove total economic value (TEV) in Takalar District, South Sulawesi ranges from 4,000 to 8,000 USD per hectare, compared to commercial aquaculture that provides net benefits of 3,000 USD per hectare. Indrayanti et al (2015) studied the value of mangrove ecosystem services in Blanakan Subang Bay, West Java obtained the TEV at Rp. 3,815,790,110.97 per year for 782.34 ha mangrove area. Other study by Suharti et al (2016) found the total value of mangroves in East Sinjai with a total area of 758 ha was Rp. 37,535,809,496 per year.

Mangrove ecosystem management in Indonesia. Management of mangrove ecosystems faces a complexity of problems. Mangrove ecosystems as renewable resources provide various types of life support products (Kusmana 2015a), but the ecosystem is subjected to continuous pressure due to natural factors and human activities. Based on the literature reviews, mangrove ecosystem received considerable attention in the theme of ecosystem management in Indonesia. The aspects of the study and coverage area of the studies are diverse, including the conceptual (Effendy 2009; Kusmana 2015a), biophysical analysis (Fahrian et al 2015; Zurba et al 2017), social analysis (Ritohardoyo & Ardi 2011; Harahab 2011; Kustanti et al 2015; Febryano et al 2015), economic valuation (Ruitenbeek 1994; Saprudin & Halidah 2012), institutional (Suharti et al 2016; Kuvaini et al 2017), and regulation (Sunyowati et al 2016). Other studies were done on sustainability status (Mukhlisi et al 2014; Theresia et al 2015; Karlina et al 2016), system model (Datunsolang 2016) and management strategies (Wijayanto et al 2013; Yenny et al 2017; Lugina et al 2017). Those studies are generally focused on sustainability and socio-economic aspect, while the study on analysis ecosystem services and institutional structure are still limited.

Management of mangrove ecosystems requires an approach that can connect the interests of environmental sustainability and benefits for human wellbeing in a balanced way. One of the efforts can be done is by comprehensive reviewing of ecosystem services. It is supported by several aspects that have been widely discussed in various studies, including:

1. Ecology - mangrove ecosystem has been recognized to have the function and benefits for the environment and the preservation of biodiversity. Based on Kusmana (2014), mangrove resources in Indonesia have been supporting many kinds of human needs ;

2. Socio-economic - mangrove ecosystem plays an important role for the community wellbeing such as food and livelihood sources ;

3. Institutional - mangrove ecosystem is a means of managing both protection, rehabilitation, and even utilization that involves the attention and participation of many parties such as government, private, NGO, and society. Since 2013, the Indonesian government has initiated the formation of a National Mangrove Working Group (KKMN) that consists of cross-sector/institutional/NGO ;

4. Regulations and laws - mangrove ecosystem in Indonesia already has a regulatory instrument that specifically focuses on the national management strategy, namely Presidential Regulation no. 73 of 2012. In addition, it is supported by Government Regulation no. 26 of 2008 concerning about national spatial plan, Government Regulation no. 73 of 2013 concerning about swamps, Presidential Regulation No. 51 of 2016 concerning about coastline boundaries.

The concept of ecosystem services is also used by academics, researchers and decision makers to support and explain environmental management and biodiversity conservation strategies (Martín-López et al 2012). Ecosystem services still need to be studied as a basis for the development strategy for mangrove ecosystem management because it is an important part in the management of mangrove ecosystems (Schmitt & Duke 2015; Karlina et al 2016). According to Brander et al (2012) potential research on mangrove ecosystems in the future is research that combines ecology and economy to make a model of supply and service of mangrove ecosystem. Policies and programs are becoming more complex with the bureaucracy and authority involved in mangrove conservation, but it is still a key for the sustainability of mangrove and coastal ecosystem management (Carter et al 2015). Therefore, a new and more integrative approach is needed to assess sustainable development (Turner et al 2016), including the management of mangrove ecosystems.

Ecosystem service approaches can be applied in the context of mangrove ecosystem management as shown in Figure 1. Mangrove ecosystems face various pressures and dynamic changes that will also impact on ecosystem services and human life, thus it is necessary to develop sustainable ecosystem service-based management strategies.

One of the challenges of managing mangrove ecosystems is linking dynamic mangrove ecosystems with complex socio-economic life of communities such as mangrove positions near settlements and in urban areas. Management of mangrove ecosystems in the future also need to be oriented broadly to be able to measure the importance of mangrove ecosystem services for the community itself. Well managed mangrove ecosystems have the potential to have good ecosystem services and will support the sustainability of mangrove development. The role of mangrove ecosystems also requires sustainable mangrove ecosystem management. It is supported by three important pillars, namely ecology, social and economy which are covered by appropriate institutional and regulation (Kusmana 2015a). Mangroves can not be ignored because their ecosystem services have distinctive characteristics that indicate that ecosystems provide services and have value for human wellbeing.

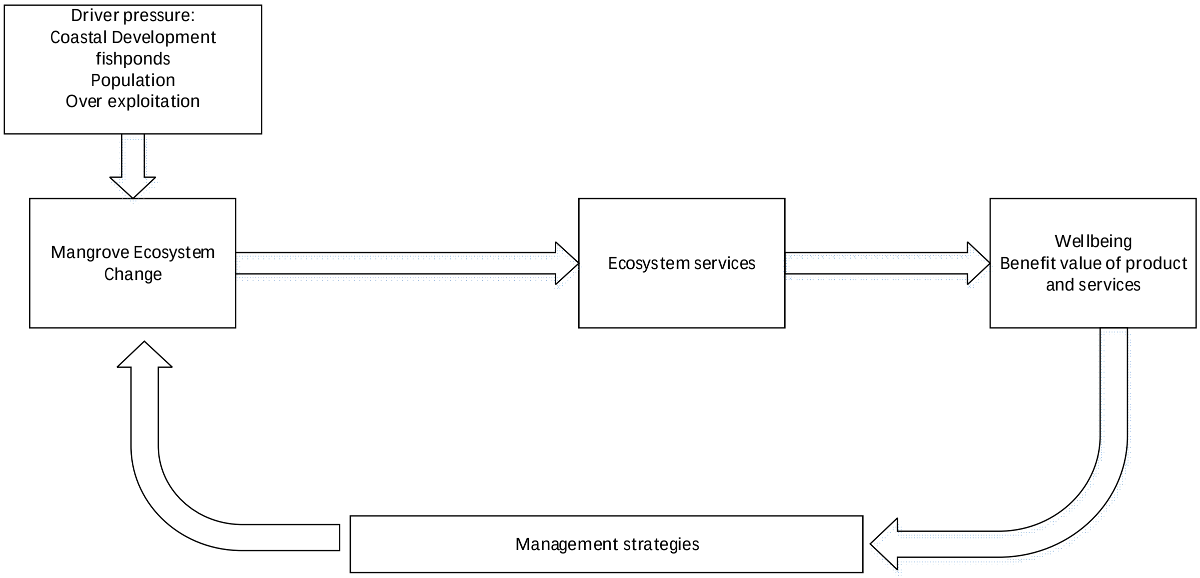

Figure 1. The application of ecosystem services approach on mangrove management (adopted from De Groot et al 2010a; Haines-Young & Potschin 2010).

Study, analysis, and strategy of mangrove ecosystem services. A review of mangrove ecosystem service management is conducted as a strategy to develop management policy to be more able to guarantee ecosystem services both in the present and in the future. Several studies that have been conducted previously provided an illustration of the importance of ecosystem service management (Mukherjee et al 2014; Kusmana 2015a; Carter et al 2015; Kustanti et al 2015; Vo et al 2015; Malik et al 2015a; Ilman et al 2016; Orchard et al 2016; Suharti et al 2016). Studies on ecosystem service approaches are also widely conducted (De Groot et al 2010a; De Groot et al 2010b; Haines-Young & Potschin 2010; Martín-López et al 2012; Elliff & Kikuchi 2015; Moore et al 2017). Researches on mangroves management related to ecosystem services have been developed, those are:

a. Analysis of ecosystem service conditions. Assessment of ecosystem services can be assessed by analyzing conditions and indicators of the ecosystem service. This aspect is crucial because directly related to the processes occurring in the ecosystem and will have an impact on the availability of ecosystem services. Similarly with mangrove ecosystems, intensive mangrove forest use has had an impact on biodiversity and mangrove ecosystem services (Malik et al 2015a). Therefore, knowledge of the status of mangrove forests is essential for better planning and management (Schmitt & Duke 2015). A study conducted by Malik et al (2015a) has assessed the ecological impact of mangrove utilization and the level of exploitation of ecosystem services in mangrove forests of South Sulawesi. Analysis of the mangrove ecosystem condition and its services is identified either directly or indirectly and analyzed according to the characteristics, coverage areas and categories specified. Geographic information systems (GIS) and remote sensing are used in various areas including in the management of mangrove ecosystems. Spatial analysis through GIS and remote sensing can assist spatially in mapping ecosystem services conditions. Ecosystem service mapping is crucial to understand the contribution of ecosystems to human wellbeing and supporting policies that impact natural resources (Burkhard & Maes 2017). Conservation and management of effective mangrove habitats need to consider remote sensing and GIS based on a comprehensive data approach (Ghosh et al 2015). Several studies related to mangrove ecosystem services using GIS approach and remote sensing have been conducted, such as Omo-Irabor et al (2011), reviewed comprehensively the use of socio-economic and environmental criteria with the opinion of expert, GIS, and SMCA (Spatial Multi Criteria Analysis) for vulnerability assessment of mangroves. Atkinson et al (2016) has assessed the value and priority of mangrove ecosystem services using spatial GIS and cost benefit of ecosystem services in decision making. Studies with GIS and remote sensing approaches can provide spatial advantages, one of which can generate significant ecological and economic benefits by obtaining real time data from unreachable area (Ghosh et al 2015). However, there are several things that need to be considered, including ecosystem services that must be assessed in the right spatial context and economic valuations that can support decisions so that policies are more useful (Vo et al 2015).

b. Social economics and valuation. Socioeconomic studies of mangrove ecosystem management related to ecosystem services have also received much attention in line with the dynamic changes and complexity that occur in mangrove ecosystem. Study of Orchard et al (2016) has reviewed the dynamics of mangrove systems in Southeast Asia by linking livelihoods with the services of mangrove ecosystems. Other socio-economic studies are economic valuations as conducted by Uddin et al (2013) that implement economic valuation of ecosystem services for protected areas of mangrove ecosystem in Sundarbarns, Bangladesh. Economic valuation of the mangrove ecosystem is quite widely studied, although not many of the result were used as one of the foundations in policy making. Valuation of ecosystem services highly depends on services from the nature, such as ecosystem functions that produce goods and services that can be sold with various alternative methods (Salem & Mercer 2012). Various types of monetary valuation measurements are used according to the type of ecosystem services, although it does not allow to explain the scope of the monetary value of all ecosystem services (De Jonge et al 2012). Several methods of economic valuation are used in the valuation of mangrove ecosystem services as shown in Table 2.

Table 2

Economic valuation method of mangrove ecosystem services

Method	*Description*	*Example application*
TCM	The revealed assessment method to assess the non-use benefit based on the observed behavior of individual expenditures for travel	Indrayanti et al (2015); Fitriana et al (2017).
MM	An assessment obtained directly from the amount a person must pay for goods and services such as timber products	Uddin et al (2013); Malik et al (2015b); Vo et al (2015); Ye et al (2016); Suharti et al (2016).
HPM	Describes an assessment of a thing (goods or service) that is perceived because of pleasure characteristic, such as beautiful scenery, convenience or other characteristics	Syukri (2016).
PA	The value of services assessed by the impact of these services on economic outcomes (e.g. increased shrimp yields from wetland increases)	Malik et al (2015b).
CVM	Non-market valuation which is a direct method for economic assessment through willingness to pay (WTP)	Suharti et al (2016).
CE	Choice experiment is a choice technique. It allows reveal to the role of an attribute that causes an individual to choose an object from several alternative object choices	McDonough et al (2014).
RC	Calculates the loss of natural system services at the cost incurred to replace the service	Malik et al (2015b); Vo et al (2015); Suharti et al (2016).
AC	Calculating services based on avoidable expenses such as clean water reduces the cost of diarrhea treatment	-
REA/ HEA	The damage assessment method based on calculating the scale of the restoration project to restore the resource service to the initial conditions	Winarno et al (2016).
BoE	Methods economic valuation on marketed components such as the calculation of economic losses due to pollution to health	-
BT	Transfers from the alleged value of non-market benefits from other sites to the research sites	Brander et al (2012); Malik et al (2015b); Vo et al (2015); Ye et al (2016); Suharti et al (2016).

The description according to Fauzi (2014); Turner et al (2016). TCM : Travel Cost Method; MM: Market Method; HPM: Hedonic Price Method; PA: Production Approach, CVM: Contingent Valuation Method; CA: Conjoint Analysis; RC: Replacement Cost; AC: Avoidance Cost; REA/HEA: Resource Equivalency Analysis/Habitat Equivalency Analysis; BoE: Back of the envelope; BT: Benefit Transfer.

c. System structure. System is a unity of efforts, consisting of interrelated parts regularly, and trying to achieve goals in a complex environment (Marimin & Maghfiroh 2010). Structure describes the arrangement of the elements and relationships between elements in forming a system. Every system approach always prioritizes the study of the system structure both explanatory and as policy support (Eriyatno 2012). Management of mangrove ecosystem services can be analyzed by a system approach because mangrove ecosystem is a complex system. Understanding of the system structure is one way to achieve the effective management objectives of the complex system.

Structural analysis is a good and powerful design tool for sharing knowledge and experience (Omran et al 2014). The core of this method is the measurement of the relationship between variables and the simplification of the system by selecting the most influential external variables and the most sensitive internal variables (key variables) (Fierro 2015). The most popular structuring tool for indirect relationship is MICMAC, whereas for direct relationship is used Interpretative Structural Modeling (ISM) technique (Eriyatno 2012).

MICMAC MICMAC (cross-impact matrix multiplication applied to classification) is a structural analysis (Suprun et al 2016) that uses Boolean matrix to classify variables based on strength and dependence (Ambrosio-Albala & Delgado 2008). Structural analysis provides simulated reflection with expert skill and can be easily applied to problem formulation in a matrix design and supports qualitative studies (Omran et al 2014). MICMAC is one of the standard tools of scenario analysis built by Michel Godet, which presents a structured process in identifying variables for scenarios that may occur in the future based on expert opinions on system interactions (Veltmeyer & Sahin 2014). MICMAC method is performed by defining the problem and proceeding with 3 following stages (Benjumea-Arias et al 2016; Nazarko et al 2017):

- identification of internal and external variables;
- analysis of relationship between variables in the system;
- identification of key variable qualifies: direct and indirect classification.

Furthermore, the influence and dependence analysis is obtained through the position of the variable indicator in the quadrant. Variables can be in the variable power, autonomous, conflict or the output variables depending on the level of influence and dependence it has.

d. Future prospective strategies. The characteristic of strategies decisions is long term, dynamic environment and influences factors with very low certainty (Marimin & Maghfiroh 2010). Godet (2000) has described scenario analysis, the concept of prospective strategy, and the stages of scenario analysis process along with its usable tools and case study examples. A prospective method is as a tool for generalize of strategic knowledge to design future sustainability and allowing for designing different future scenarios by planning the transformation of the current situation into the expected future (Fierro 2015). Aryanto & Yuniarty (2010) mentioned that prospective analysis is appropriately used for policy strategy design and has two main uses, namely: preparing strategic actions that need to be done and to see if the changes are needed in the future. The objectives of identifying future conditions are to identify their characteristics and impacts, and to calculate the relative probability of occurrence (Bishop et al 2007).

Strategy is needed to overcome the mangrove ecosystem pressure. Management strategies should also be developed to achieve the sustainability objectives of the mangrove ecosystem to ensure the sustainability of ecological and socio-economic functions and not harm the lives of present and future generations (KKMTN 2013). Iftekhar & Islam (2004) mention the key strategies of mangrove management such as holistic management adoption, conservation and biodiversity improvement, impact zone management, government and non-government collaboration in management, community participation, non-exploitative utilization promotion, and sustainability planting on deltaber.

Several studies of mangrove ecosystem management strategies have been conducted including Iftekhar & Islam (2004) assessed the management of mangrove ecosystem using strategy analysis, and Atkinson et al (2016) assessed the management of mangrove ecosystems using cost-effectiveness analysis with the cost benefit of ecosystem services for several scenarios to obtain effective management. Other studies such as Faperi et al (2015), reviewed mangrove degradation management strategies using vegetation analysis, structural equation modeling (SEM), AHP and SWOT. Another prospective method that has been used in other fields is SMIC-Prob-Expert. SMIC-Prob-Expert is a cross-impact analysis built by Michael Godet to combine beneficial aspects, both quality and quantity (Lakner & Baker 2014). SMIC (Cross Impact Systems and Matrices) has several advantages among cross impact methods, including easy to use with the help of questionnaires, quick, and inexpensive. These characteristics make it easy to explain the results. However, this method requires a lot of thought in giving information treatment to choose an important hypothesis. The strategy hypothesis formulation also requires structural analysis and understanding of key variables. The results of the SMIC method are scenario hierarchy and sensitivity analysis.

Research prospect of mangrove ecosystem services. Ecosystem services as previously reviewed have an important position in the management of mangrove ecosystems and may assist describe the ecosystem relationship with human life. There are several assessment opportunities related to the management of mangrove ecosystem services that can be further examined, including:

1. mangrove ecosystem condition that focuses on ecosystem service in accordance with the region;
2. economic valuation of mangrove ecosystem services is important in determining the value and can be a consideration in the management strategy;
3. system structure of the mangrove ecosystem management variables associated with the ecosystem services and main variable analysis;
4. pressures and complexity that exist in the mangrove ecosystem and its survival strategies in facing future changes (prospective) based on current conditions in the management of ecosystem services.

Aspects of the study as previously described certainly integrate mangrove ecosystem services into challenges in the development of management strategies. Although ecosystem services from a number of existing studies may connecting ecosystem and community wellbeing, yet the existing literature is limited, particularly in linking ecosystem services to future management strategies. This is particularly important considering the dynamic nature of ecosystems and external pressures such as continuous population increases. Existing mangrove ecosystem management strategies have not fully reviewed ecosystem services comprehensively in order to anticipate changes in the ecosystem and ensure services to be provided. In addition, the review can be an answer in the context of a sustainable development assessment requiring a new and more integrative approach (Turner et al 2016), included in the management of mangrove ecosystem services in Indonesia.

Conclusions. Mangroves have ecosystem services that are beneficial for human life and other biota, but continue to experience destruction and decline due to excessive exploitation. Increasingly large and complex pressures on mangrove ecosystems will greatly increase the pressure on sustainability of ecosystem services. This should be considered by policy makers in mangrove ecosystem management strategies. Ecosystem services will also be closely linked to the characteristics of each region and the value that requires in-depth analysis. The study of mangrove ecosystem management variables will also be very useful in decision making for development of management strategies in the future. This article contributes to provide a road map for research opportunities in mangrove ecosystem management especially in the context of ecosystem services. This study will become an input in answering the challenges of managing complex and dynamic mangrove ecosystems in Indonesia. Therefore, the development of ecosystem management strategies is still likely to be studied as an effort to achieve sustainable management objectives.

Acknowledgements. This work was supported by the Marine and Fisheries Education Center, Marine and Fisheries Research and Human Resource Agency, Ministry of Marine and Fisheries Affairs of the Republic of Indonesia.

References

Ambrosio-Albala M., Delgado M., 2008 Understanding rural areas dynamics from a complex perspective. An application of prospective structural analysis. 12th Congress of the European Association of Agrarian Economists (EAAE), 15 pp.

Aryanto R., Yuniarty Y., 2010 [Model of strategic prospective management performance at tour and travel company]. Binus Business Review 1(2):448-460. [in Indonesian]

Atkinson S. C., Jupiter S. D., Adams V. M., Ingram J. C., Narayan S., Klein C. J., Possingham H. P., 2016 Prioritising mangrove ecosystem services results in spatially variable management priorities. PLoS ONE 11(3):e0151992.

Barbier E. B., 2016 The protective service of mangrove ecosystems: a review of valuation methods. Marine Pollution Bulletin 109(2):676-681.

Barbier E. B., Hacker S. D., Kennedy C., Koch E. W., Stier A. C., Silliman B. R., 2011 The value of estuarine and coastal ecosystem services. Ecological Monographs 81(2):169-193.

Benjumea-Arias M., Castañeda L., Valencia-Arias A., 2016 Structural analysis of strategic variables through MICMAC use: case study. Mediterranean Journal of Social Sciences 7(4):11-19.

Bishop P., Hines A., Collins T., 2007 The current state of scenario development: an overview of techniques. Foresight 9(1):5-25.

Brander L. M., Wagtendonk A. J., Hussain S., McVittie A., Verburg P. H., de Groot R. S., van der Ploeg S., 2012 Ecosystem service values for mangroves in Southeast Asia: a meta-analysis and value transfer application. Ecosystem Services 1(1):62-69.

Burkhard B., Maes J., 2017 Mapping ecosystem services. Pensoft Publishers, Sofia, Bulgaria, 374 pp.

Carter H. N., Schmidt S. W., Hirons A. C., 2015 An international assessment of mangrove management: incorporation in integrated coastal zone management. Diversity 7(2):74-104.

Costanza R., d'Arge R., de Groot R., Faber S., Grasso M., Hannon B., Limburg K., Naeem S., O'Neill R. V., Paruelo J., Raskin R. G., Sutton P., van den Belt M., 1997 The value of the world's ecosystem services and natural capital. Nature 387(6630):253-260.

Datunsolang A., 2016 [Coastal area management model in the framework of mangrove forests]. Indonesian Journal of Environmental Education and Management 1(2):98-114. [in Indonesian]

De Groot R., Fisher B., Christie M., Aronson J., Braat L., Gowdy J., Haines-Young R., Maltby E., Neuville A., Polasky S., Portela R., Ring I., 2010a Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation. The Economics of Ecosystems and Biodiversity: The Ecological and Economic Foundations, 40 pp.

De Groot R. S., Alkemade R., Braat L., Hein L., Willemen L., 2010b Challenges in integrating the concept of ecosystem services and values in landscape planning, management and decision making. Ecological Complexity 7(3):260-272.

De Jonge V. N., Pinto R., Turner R. K., 2012 Integrating ecological, economic and social aspects to generate useful management information under the EU Directives' "ecosystem approach." Ocean and Coastal Management 68:169-188.

Effendy M., 2009 [Integrated coastal management: solutions for spatial utilization, resource utilization and capacity utilization of optimal and sustainable coastal area]. Jurnal Kelautan 2(1):81-86. [in Indonesian]

Elliff C. I., Kikuchi R. K. P., 2015 The ecosystem service approach and its application as a tool for integrated coastal management. Natureza & Conservação 13(2):105-111.

Eriyatno, 2012 [Improving management quality and effectiveness]. Widya G., Larasati L. (eds), Surabaya, Indonesia, 187 pp. [in Indonesian]

Fahrian H. H., Putro S. P., Muhammad F., 2015 [Potential of ecotourism in mangrove area, Mororejo Village, Kendal District]. Biosaintifika 7(2):104-111. [in Indonesian]
Faperi S., Supriharyono, Hendrarto I. B., Radjasa O. K., 2015 Management strategies of mangrove degradation in coastal areas of Brebes Regency, Central Java, Indonesia. Journal of Coastal Zone Management 18(2):1000401.
Fauzi A., 2014 [Economic valuation and assessment of damage to natural resources and environment]. IPB Press, Bogor, 246 pp. [in Indonesian]
Fauzi A., Anna S., 2005 [Modeling of fisheries and marine resources for policy analysis]. PT Gramedia Pustaka Utama, Jakarta, 343 pp. [in Indonesian]
Febryano I. G., Suharjito D., Darusman D., Kusmana C., Hidayat A., 2015 [Actors and power relation in mangrove management in Pesawaran Regency, Lampung Province, Indonesia]. Jurnal Analisis Kebijakan Kehutanan 12(2):125-142. [in Indonesian]
Fierro G. G., 2015 Strategic prospective methodology to explore sustainable futures. Journal of Modern Accounting and Auditing 11(11):606-614.
Fisher B., Turner R. K., Morling P., 2009 Defining and classifying ecosystem services for decision making. Ecological Economics 68(3):643-653.
Fitriana V., Abidin Z., Endaryanto T., 2017 [Estimation of demand and economic value of Angke Kapuk Nature Park in North Jakarta]. JIIA 5(3):267-274. [in Indonesian]
Ghosh S., Bakshi M., Bhattacharyya S., Nath B., Chaudhuri P., 2015 A review of threats and vulnerabilities to mangrove habitats: with special emphasis on east coast of India. Journal of Earth Science and Climate Change 6(4):1000270.
Giri C., Ochieng E., Tieszen L. L., Zhu Z., Singh A., Loveland T., Masek J., Duke N., 2011 Status and distribution of mangrove forests of the world using earth observation satellite data. Global Ecology and Biogeography 20(1):154-159.
Godet M., 2000 The art of scenarios and strategic planning: tools and pitfalls. Technological Forecasting and Social Change 65(1):3-22.
Gómez-Baggethun E., De Groot R., Lomas P. L., Montes C., 2010 The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. Ecological Economics 69(6):1209-1218.
Haines-Young R., Potschin M., 2010 The links between biodiversity, ecosystem services and human well-being. In: Ecosystem ecology: a new synthesis. Raffaelli D., Frid C. (eds), BES Ecological Reviews Series, CUP, Cambridge University Press, pp. 110-139.
Haines-Young R., Potschin M., 2013 Common International Classification of Ecosystem Services (CICES): consultation on Version 4, August-December 2012. Report to the European Environment Agency. EEA Framework Contract No EEA/IEA/09/003, 34 pp.
Harahab N., 2009 [The influence of mangrove ecosystem as their role for catching productivity (case study in Pasuruan, East Java)]. Jurnal Perikanan 11(1):100-106. [in Indonesian]
Harahab N., 2009 [Effect of mangrove forest ecosystem on capture fishery production (case study in Pasuruan residence, East Java)]. Jurnal Perikanan Universitas Gadjah Mada 11(1):100-106. [in Indonesian]
Häyhä T., Franzese P. P., 2014 Ecosystem services assessment: a review under an ecological-economic and systems perspective. Ecological Modelling 289:124-132.
Iftekhar M. S., Islam M. R., 2004 Managing mangroves in Bangladesh: a strategy analysis. Journal of Coastal Conservation 10(1-2):139-146.
Ilman M., Wibisono I. T. C., Suryadiputra I. N. N., 2011 State of the art information on mangrove ecosystems in Indonesia. Wetlands International - Indonesia Programme, Bogor, 56 pp.
Ilman M., Dargusch P., Dart P. J., Onrizal O., 2016 A historical analysis of the drivers of loss and degradation of Indonesia's mangroves. Land Use Policy 54:448-459.
Indrayanti M. D., Fahrudin A., Setiobudiandi I., 2015 [Valuation of mangrove ecosystem services in Blanakan Bay, Subang District]. Jurnal Ilmu Pertanian Indonesia 20(2):91-96. [in Indonesian]

Kairo J. G., Dahdouh-Guebas F., Bosire J., Koedam N., 2001 Restoration and management of mangrove systems - a lesson for and from the East African region. South African Journal of Botany 67(3):383-389.
Karlina E., Kusmana C., Marimin, Bismark M., 2016 [Analysis of sustainability of mangrove protection forest management in Batu Ampar, Kubu Raya Regency, West Kalimantan Province]. Jurnal Analisis Kebijakan 13(3):201-219. [in Indonesian]
KKMTN, 2013 [National strategy of mangrove ecosystem management in Indonesia (book 1)]. Jakarta, Indonesia, 24 pp. [in Indonesian]
Kuenzer C., Bluemel A., Gebhardt S., Vo Quoc T., Dech S., 2011 Remote sensing of mangrove ecosystems: a review. Remote Sensing 3(5):878-928.
Kusmana C., 2014 Distribution and current status of mangrove forests in Indonesia. In: Mangrove ecosystems of Asia: status, challenges and management strategies. Springer, New York, pp. 37-60.
Kusmana C., 2015a Integrated sustainable mangrove forest management. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 5(1):1-6.
Kusmana C., 2015b [Technique of Guludan as method of planting of mangrove on land flooded with deep water]. In: Scientific Oration of Professor of IPB. Bogor, Indonesia, 95 pp. [in Indonesian]
Kusmana C., Purwanegara T., 2015 [Technique of bunds as solution of mangrove planting method on deep waterlogged land]. Risalah kebijakan pertanian dan lingkungan: Rumusan Kajian Strategis Bidang Pertanian dan Lingkungan 1(3):165-171. [in Indonesian]
Kusmana C., Sukristijiono, 2016 Mangrove resources uses by local community in Indonesia. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 6(2):217-224.
Kustanti A., Nugroho B., Nurrochmat D. R., Okimoto Y., 2015 [Evolution of ownership rights in the management of mangrove forest ecosystems in Lampung Mangrove Center]. Risalah kebijakan pertanian dan lingkungan: Rumusan Kajian Strategis Bidang Pertanian dan Lingkungan 1(3):143-158. [in Indonesian]
Kuvaini A., Hidayat A., Kusmana C., Basuni S., 2017 Institutional resilience of pesantren in mangrove forest management in Kangean Island, East Java Province, Indonesia. AACL Bioflux 10(6):1475-1482.
Lakner Z., Baker G. A., 2014 Struggling with uncertainty: the state of global agri-food sector in 2030. International Food and Agribusiness Management Review 17(4): 141-176.
Lugina M., Alviya I., Indartik, Pribadi M. A., 2017 [Strategy of mangrove management in Ngurah Rai Grand Forest Park]. Jurnal Analisis Kebijakan Kehutanan 14(1):61-77. [in Indonesian]
Luque S., Gonzalez-Redin J., Fürst C., 2017 Mapping forest ecosystem services. In: Ecosystem services mapping. Burkhard B., Maes J. (eds), Pensoft Publishers, Sofia, pp. 324-328.
Macintosh D., Epps M. M., Abrenilla O., 2010 Ecosystem approaches to coastal resources management: the case for investing in mangrove ecosystems. In: Food for all: investment forum for food security in Asia and the Pacific – issues, innovations, and practices. 7-9 July 2010 ADB Headquarters, Manila, Phillipines, 15 pp.
Malik A., Fensholt R., Mertz O., 2015a Mangrove exploitation effects on biodiversity and ecosystem services. Biodiversity and Conservation 24(14):3543-3557.
Malik A., Fensholt R., Mertz O., 2015b Economic valuation of mangroves for comparison with commercial aquaculture in South Sulawesi, Indonesia. Forests 6(9):3028-3044.
Marimin, Maghfiroh N., 2010 [Application of decision making techniques in supply chain management]. IPB Press, Bogor, 281 pp. [in Indonesian]
Martín-López B., Iniesta-Arandia I., García-Llorente M., Palomo I., Casado-Arzuaga I., Del Amo D. G., Gómez-Baggethun E., Oteros-Rozas E., Palacios-Agundez I., Willaarts B., González J. A., Santos-Martín F., Onaindia M., López-Santiago C., Montes C., 2012 Uncovering ecosystem service bundles through social preferences. PLoS ONE 7(6):e38970.

McDonough K., Hutchinson S. L., Moore T., Hutchinson J. M. S., 2017 Analysis of publication trends in ecosystem services research. Ecosystem Services 25:82-88.
McDonough S., Gallardo W., Berg H., Trai N. V., Yen N. Q., 2014 Wetland ecosystem service values and shrimp aquaculture relationships in Can Gio, Vietnam. Ecological Indicators 46:201-213.
Moore D. W., Booth P., Alix A., Apitz S. E., Forrow D., Huber-Sannwald E., Jayasundara N., 2017 Application of ecosystem services in natural resource management decision making. Integrated Environmental Assessment and Management 13(1):74-84.
Millennium Ecosystem Assessment, 2003 Ecosystems and human well-being: a framework for assessment authors. Island Press, 1718 Connecticut Avenue, N.W., Suite 300, Washington, DC, 236 pp.
Millennium Ecosystem Assessment, 2005 Ecosystems and human well-being: current state and trends. Volume 1. In: Ecosystems and human well-being: current state and trends: findings of the Condition and Trends Working Group. Hassan R., Scholes R., Ash N. (eds), 47 pp.
Mukherjee N., Sutherland W. J., Dicks L., Hugé J., Koedam N., Dahdouh-Guebas F., 2014 Ecosystem service valuations of mangrove ecosystems to inform decision making and future valuation exercises. PLoS ONE 9(9):e107706.
Mukhlisi, Hendrarto I. B., Purnaweni H., 2014 [Status of sustainability of mangrove forest management in Sidodadi Village, Padang Cermin Sub District, Pesawaran of Lampung Province]. Jurnal Geografi 11(1):58-70. [in Indonesian]
Muraleedharan P., Swarupanandan K., Anitha V., Ajithkumar C., 2009 The conservation of mangroves in Kerala: economic and ecological linkages. Division of Forestry and Human Dimension, Kerala Forest Research Institute, Peechi, 47 pp.
Murdiyarso D., Purbopuspito J., Kauffman J. B., Warren M. W., Sasmito S. D., Donato D. C., Manuri S., Krisnawati H., Taberima S., Kurnianto S., 2015 The potential of Indonesian mangrove forests for global climate change mitigation. Nature Climate Change 5(12):1089-1092.
Nazarko J., Ejdys J., Halicka K., Nazarko Ł., Kononiuk A., Olszewska A., 2017 Structural analysis as an instrument for identification of critical drivers of technology development. Procedia Engineering 182:474-481.
Omo-Irabor O. O., Olobaniyi S. B., Akunna J., Venus V., Maina J. M., Paradzayi C., 2011 Mangrove vulnerability modelling in parts of western Niger Delta, Nigeria using satellite images, GIS techniques and spatial multi-criteria analysis (SMCA). Environmental Monitoring and Assessment 178(1-4):39-51.
Omran A., Khorish M., Saleh M., 2014 Structural analysis with knowledge-based MICMAC approach. International Journal of Computer Applications 86(5):36-43.
Orchard S. E., Stringer L. C., Quinn C. H., 2016 Mangrove system dynamics in Southeast Asia: linking livelihoods and ecosystem services in Vietnam. Regional Environmental Change 16(3):865-879.
Peraturan Pemerintah No. 26, 2008 [Government Regulation of the Republic of Indonesia Year 2008 on National Spatial Planning]. [in Indonesian]
Peraturan Presiden No. 73, 2012 [Presidential Regulation No. 73/2012 on National Strategy on Mangrove Ecosystem Management]. [in Indonesian]
Peraturan Pemerintah No. 73, 2013 [Government Regulation of the Republic of Indonesia of 2013 on Swamp]. [in Indonesian]
Peraturan Presiden No. 51, 2016 [Regulation of the President of the Republic of Indonesia Year 2016 Concerning Coastal Border Limits]. [in Indonesian]
Polidoro B. A., Carpenter K. E., Collins L., Duke N. C., Ellison A. M., Ellison J. C., Farnsworth E. J., Fernando E. S., Kathiresan K., Koedam N. E., Livingstone S. R., Miyagi T., Moore G. E., Ngoc Nam V., Ong J. E., Primavera J. H., Salmo S. G., Sanciangco J. C., Sukardjo S., Wang Y., Yong J. W., 2010 The loss of species: mangrove extinction risk and geographic areas of global concern. PLoS ONE 5(4):e10095.

Ritohardoyo S., Ardi G. B., 2011 [Mangrove forest management policy direction: coastal case of Teluk Pakedai Sub-district, Kubu Raya District, West Kalimantan Province]. Jurnal Geografi 8(2):83-94. [in Indonesian]
Ruitenbeek H. J., 1994 Modelling economy-ecology linkages in mangroves: economic evidence for promoting conservation in Bintuni Bay, Indonesia. Ecological Economics 10:233-247.
Salem M. E., Mercer D. E., 2012 The economic value of mangroves: a meta-analysis. Sustainability 4(3):359-383.
Saprudin, Halidah, 2012 [The potential and value of environmental services benefits of mangrove forest in Sinjai district of South Sulawesi]. Jurnal Penelitian Hutan dan Konservasi Alam 9(3):213-219. [in Indonesian]
Schmitt K., Duke N. C., 2015 Mangrove management, assessment and monitoring. In: Tropical forestry handbook. Köhl M., Pancel L. (eds), Springer, Berlin, Heidelberg, pp. 1-29.
Sina I., Maryunani, Batoro J., Harahab N., 2017 Analysis of total economic value of ecosystem mangrove forest in the coastal zone Pulokerto Village District of Kraton Pasuruan Regency. Interntional Journal of Ecosystem 7(1):1-10.
Sonjaya J., 2007 [Policy for mangroves: reviewing cases and formulating policies]. International Union for Conservation of Nature and Natural Resources and Mangrove Action Project (IUCN & Mangrove Action Project–Indonesia), 46 pp. [in Indonesian]
Suharti S., Darusman D., Nugroho B., Sundawati L., 2016 Economic valuation as a basis for sustainable mangrove resource management: a case in East Sinjai, South Sulawesi. Jurnal Manajemen Hutan Tropika 22(1):13-23.
Sunyowati D., Hastuti L., Butar-Butar F., 2016 The regulation of sustainable mangroves and coastal zones management in Indonesia. Journal of Civil and Legal Sciences 6(1):1000220.
Suprun E., Sahin O., Stewart R. A., Panuwatwanich K., 2016 Model of the Russian Federation construction innovation system: an integrated participatory systems approach. Systems 4(3):29.
Syukri I., 2016 Quantifying the environmental value in western coast of Semarang City, Central Java, Indonesia. Jurnal Pengelolaan Sumberdaya Alam dan Lingkungan 6(1):97-110.
TEEB, 2010 The economics of ecosystems and biodiversity: the ecological and economic foundations. Kumar P. (ed), Earthscan Publications, United Nations Environment Programme, London, 410 pp.
Theresia, Boer M., Pratiwi N. T. M., 2015 [Sustainability status of mangrove ecosystem management in Sembilang National Park, Banyuasin Regency, South Sumatera Province]. Jurnal Ilmu dan Teknologi Kelautan Tropis 7(2):703-714. [in Indonesian]
Turner K. G., Anderson S., Gonzales-Chang M., Costanza R., Courville S., Dalgaard T., Dominati E., Kubiszewski I., Ogilvy S., Porfirio L., Ratna N., Sandhu H., Sutton P. C., Svenning J. C., Turner G. M., Varennes Y. D., Voinov A., Wratten S., 2016 A review of methods, data, and models to assess changes in the value of ecosystem services from land degradation and restoration. Ecological Modelling 319:190-207.
Uddin M. S., van Steveninck E. R., Stuip M., Shah M. A. R., 2013 Economic valuation of provisioning and cultural services of a protected mangrove ecosystem: a case study on Sundarbans Reserve Forest, Bangladesh. Ecosystem Services 5:88-93.
Veltmeyer J., Sahin O., 2014 Modelling climate change adaptation using cross-impact analysis: an approach for integrating qualitative and quantitative data. International Environmental Modelling and Software Society (iEMSs), 7th International Congress on Environmental Modelling and Software, San Diego, CA, USA, Ames D. P., Quinn N. W. T., Rizzoli A. E. (eds), 9 pp.
Vo Q. T., Küenzer C., Vo Q. M., Moder F., Oppelt N., 2012 Review of valuation methods for mangrove ecosystem services. Ecological Indicators 23:431-446.
Vo Q. T., Küenzer C., Oppelt N., 2015 How remote sensing supports mangrove ecosystem service valuation: a case study in Ca Mau Province, Vietnam. Ecosystem Services 14:67-75.

Walters B. B., Rönnbäck P., Kovacs J. M., Crona B., Hussain S. A., Badola R., Primavera J. H., Barbier E., Dahdouh-Guebas F., 2008 Ethnobiology, socio-economics and management of mangrove forests: a review. Aquatic Botany (89):220-236.
Wijayanto D., Nuriasih D. M., Huda M. N., 2013 [Strategy of mangrove tourism development in Nusa Penida waters conservation area]. Jurnal Saintek Perikanan 8(2):25-32. [in Indonesian]
Winarno S., Effendi H., Damar A., 2016 [Level of damage and estimation of claims value of mangrove ecosystem damage in Bintan Bay, Bintan Regency]. Jurnal Ilmu dan Teknologi Kelautan Tropis 8(1):115-128. [in Indonesian]
Ye S., Laws E. A., Costanza R., Brix H., 2016 Ecosystem service value for the common reed wetlands in the Liaohe Delta, Northeast China. Open Journal of Ecology 6:129-137.
Yenny M., Hendrarto B., Hidayat J. W., 2017 [Strategy of mangrove ecosystem management in Baros through consideration of ecosystem services according to perspective of service user community]. Coastal and Ocean Journal 1:91-98. [in Indonesian]
Zhang X., Lu X., 2010 Multiple criteria evaluation of ecosystem services for the Ruoergai Plateau Marshes in southwest China. Ecological Economics 69(7):1463-1470.
Zurba N., Effendi H., Yonvitner, 2017 [Management of mangrove ecosystem potential in Kuala Langsa, Aceh]. Jurnal Ilmu dan Teknologi Kelautan Tropis 9(1):281-300. [in Indonesian]

Received: 13 August 2018. Accepted: 23 November 2018. Published online: 08 February 2019.
Authors:
Achmad Sofian, Study Program of Natural Resources and Environmental Management, Graduate School of Bogor Agricultural University (IPB), Bogor 16680 Indonesia, e-mail: achmad.sofian@kkp.go.id
Cecep Kusmana, Department of Silviculture, Faculty of Forestry, Bogor Agricultural University (IPB), Bogor 16680 Indonesia, e-mail: ckmangrove@gmail.com
Akhmad Fauzi, Department of Resources and Environmental Economics, Faculty of Economics and Management, Bogor Agricultural University (IPB), Bogor 16680, Indonesia, email: fauziakhmad@gmail.com
Omo Rusdiana, Department of Silviculture, Faculty of Forestry, Bogor Agricultural University (IPB), Bogor 16680, Indonesia, email: orusdiana@gmail.com

How to cite this article:
Sofian A., Kusmana C., Fauzi A., Rusdiana O., 2019 Ecosystem services-based mangrove management strategies in Indonesia: a review. AACL Bioflux 12(1):151-166.