Trends and Future Projections for Marine Biogeochemistry Research in Indonesia

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Abstrak

Tren dan Proyeksi Penelitian Biogeokimia Laut di Indonesia

Biogeokimia sebagai ilmu sistem merupakan bidang yang relatif baru di Indonesia, jadi proyeksi kedepan perlu dilakukan untuk riset di bidang kelautan. Tujuan dari kajian ini adalah untuk memilah tren penelitian di bidang biogeokimia sekaligus menentukan kesempatan penelitian biogeokimia kelautan di Indonesia di masa yang akan datang. Analisis bibliometrik dipergunakan dalam kajian ini dengan basis data sitasi publikasi ilmiah sebagai sumber data utama. Kata kunci 'marine biogeochemistry' dipakai untuk memilah basis data secara otomatis. Analisis lanjutan yang lebih detil dilakukan pada publikasi pada tahun 2011-2013. Selain itu, data mengenai tema penelitian oseanografi pada Pusat Penelitian Oseanografi dan Badan Penelitian dan Observasi Kelautan. Berdasarkan analisis tersebut, prediksi tema riset biogeokimia kelautan di Indonesia dapat dilakukan. Topik yang mungkin menjadi riset kedepan adalah: efek pemanasan global terhadap mangrove dan terumbu karang, efek pengasaman air laut terhadap produksi primer atau organisme bentik, pergeseran distribusi spesies, peran biogeokimia spesies tertentu pada transfer materi organik. Sebagai bidang ilmu yang relatif baru, biogeokimia dapat menjadi bagian esensial pada berbagai kajian komprehensif pada ilmu kelautan, khususnya pada tema yang signifikan seperti perubahan iklim global dan pengasaman air laut.

Kata kunci: *bibliometri, biogeokimia kelautan, tren, global, proyeksi*

Abstract

Biogeochemistry as the science system is relatively new field in Indonesia, therefore, projection is needed for the future research in marine science. The objectives of this study are to specify the trends in biogeochemistry research topics and to determine the opportunities for marine biogeochemistry research in Indonesia. Bibliometric analysis was used with citation databases as the main data. The keyword 'marine biogeochemistry' was used to sort the database. We conducted the further analysis mostly in publications from 2011-2013. The data about research themes related to oceanography in Indonesia were collected from Research Center for Oceanography and Institute for Marine Research and Observation). On the basis of the analyses, we tried to predict the likely main themes in marine biogeochemistry in Indonesia in the future. The likely topics are: the effects of global warming on mangroves and coral reefs, the effects of ocean acidification on primary production or benthic organisms, shifts in species distribution, and the biogeochemical role of certain species in organic material transfer. It is suggested that the relatively new discipline of biogeochemistry must be an essential part of any comprehensive study of marine science, especially in significant areas such as global climate change and ocean acidification.

Keywords: *bibliometry, marine biogeochemistry, trend, global, projection*

Introduction

Biogeochemistry is a discipline with relevance in many areas of marine science. Libes (2009) stated that there are ten popular topics in marine biogeochemistry. Those topics are 1) hydrological cycle, 2) redox chemistry in the context of microbial ecology, 3) sediment chemistry, 4) carbon, nitrogen, phosphorus cycles, 5) marine cycling of iron, 6) paleoceanography, 7) marine pollution, 8) climate change and ocean acidification, 9) hydrothermal activity, and 10) marine microbes in elemental cycling. Biogeochemistry studies in SE Asia countries have been conducted in both fresh and marine waters. Some of the studies appeared in international publications while others may only be known through local or regional publications.

Since the biogeochemistry is relatively new field and not so many researcher especially in

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Indonesia aware of this opportunity, thus it is necessary to try tracking down the trends of the research in this field. Furthermore, significant theme such as global climate change or ocean acidification should also be approached comprehensively, therefore biogeochemistry may give one of the essential part.

In this study, bibliometric trend analysis was conducted in order to reveal the global research trends in biogeochemistry. The trend analysis itself has been widely applied across many disciplines, from medicine to computer science and social science Hoonlor *et al*. (2013). Bibliometric analysis is also one of the methods which has been widely applied (Xie *et al*., 2008; Li *et al*., 2011; Zhuang *et al*., 2013). The objectives of this study are to specify the topic trends in biogeochemistry studies and to elaborate on the likely development of these studies especially in Indonesia. The main goal is to determine the opportunities for marine biogeochemistry research in Indonesia.

Materials and Methods

Most of the recent studies (*e.g.* Xie *et al*., 2008; Li *et al*., 2011; Zhuang *et al*., 2013) apply bibliometry using data from the Science Citation Index Expanded (SCI-Expanded/ 1975-present) and Conference Proceedings Citation Index-Science (CPCI-S/1990-present) from Web of Science – Web of Knowledge Thomson and Reuters (New York-USA). Xie *et al*. (2008) explains that the databases are frequently used as the source of broader reviews of scientific accomplishments. When this study was written, the Web of Science had already been updated to v.5.13 (available online: http://apps.webofknowledge.com/).

Research themes from the Research Center for Oceanography (RCO) and the Institute for Marine Research and Observation (IMRO) were categorized by topic, for example: taxonomy and biodiversity, environmental assessment, marine pollution, etc. (see results). Bibliometric analysis using keyword "marine biogeochemistry" sorted the databases of up to 1270 documents consisting of 1083 journal articles and 187 others (proceedings, review, book chapters, etc). The database of those 1270 documents were then extracted to JabRef reference manager as BibTex file format (consisting of document title, author, year of publication, journal name, abstract and cited references).

The Web of Science can automatically perform an analysis to show some parameters including the year of publication, funding agencies, territories or countries involved in the research, organizations, authors, source name (journal, proceeding, etc), document type, research areas and Web of Science's categories. The result is presented in percentages which is very useful in bibliometrics.

Further analysis was performed to assess in more detail the trend in specific topics within biogeochemistry. For instance, the keyword 'sediment' was used to sort the 1270 documents. However, this analysis excluded 150 documents published in 2010, 2003 and 2002, respectively as, technically, the BibTex file could not be extracted to the JabRef reference manager. However, as shown in the text, the review could be done manually using the text editor to findsome topics or keywords are used in the publication. Therefore, this technical problem could be minimized in order to get optimal results.

The years 2011 to 2013 show the trends in the last three years. There were 107, 117 and 132 documents published in 2011, 2012 and 2013, respectively. Those documents were categorized according to topic (*e.g.* microbial biogeochemistry, sediment, primary producer, ocean acidification). These categories then were compared to the list of globally popular topics referred to in the introduction (Libes, 2009) (see introduction).

Using the results obtained from this analysis, we tried to predict the most likely future research topics in marine biogeochemistry. The prediction was performed by considering the topic trends in oceanography research in Indonesia as well as government policy factors.

Result and Discussion

The world research trend in marine biogeochemistry

Figure 1 shows the increase in publications related to marine biogeochemistry. The study of biogeochemistry had been increasing since 1995. It is clear that its upward trend accelerated in the last decade. Among 1270 documents, oceanography is the largest relevant Web of Science Category (29%, Figure 2a) which related to marine biogeochemistry. According to the Research Area, those 1270 documents belong to: environmental science and ecology (32%), oceanography (29%), marine-fresh water ecology (26%), and the rest (13%) are in other research areas such as marine biology, pollution, etc (Figure 2b.).

Microbial ecology and the role in biogeochemistry were the leading topics in 2011 and 2013. About 15.9% of 107 publications in 2011 related to microbial activities in biogeochemistry. A

similar trend also occured in 2013, in which about 11.0% from a total 132 publications discussed this topic. For example Basu *et al*. (2011) studied the enumeration of bacteria from algae (*Trichodesmium* spp.) bloom in the Eastern Arabian Sea which addresses the bloom-specific flow of carbon to bacteria via chromophoric dissolved organic matter (CDOM) while Amano *et al*. (2011) conducted research in Vietnam about contribution of anammox bacteria to benthic nitrogen cycling in a mangrove forest.

Libes (2009) stated that the most popular topics in microbial ecology related to biogeochemistry is which related to redox chemistry. For example, Hunting and van der Geest (2011) studied the predictability of bacterial activity and denitrification in aquatic sediments with continuous measurements of redox potential. The research then suggested that the measurements of spatial and temporal redox potential profiles provide a useful parameter which reflects biogeochemical processes and the functioning of sediments. However, according to the recent publications (*e.g*. 2011-2013), microbial ecology research related to biogeochemistry tended not only in redox chemistry. Various topic independently provide new data and information, from carbonate dissolution (Puckett *et al.*, 2011) to organic matter mineralization (Weston *et al.*, 2011), from aquatic surface microlayers (Cunliffe *et al.*, 2011) to denitrifications in aquatic sediments (Hunting and van der Geest, 2011).

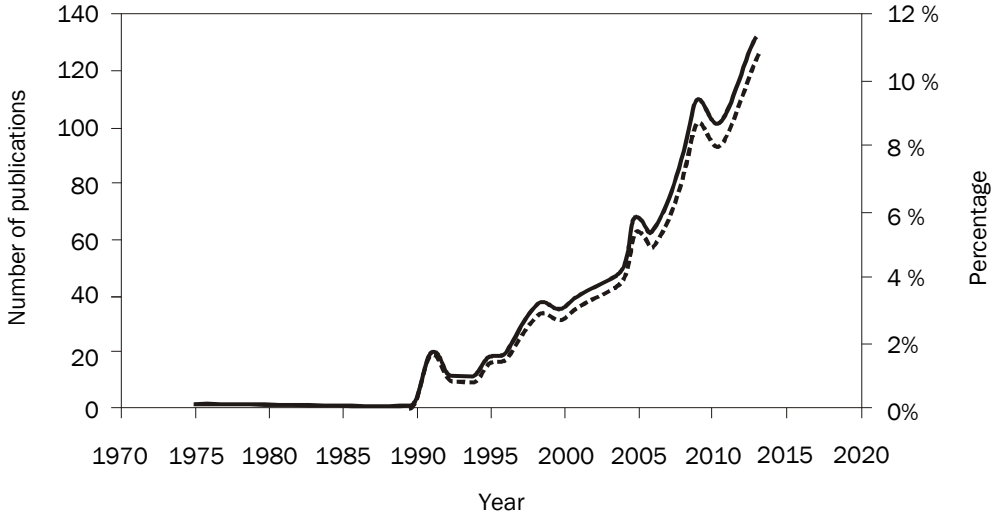

Figure 1. Increasing publications related to marine biogeochemistry up to 2013
Note : ——— = Number of publications, – – – = Percentage

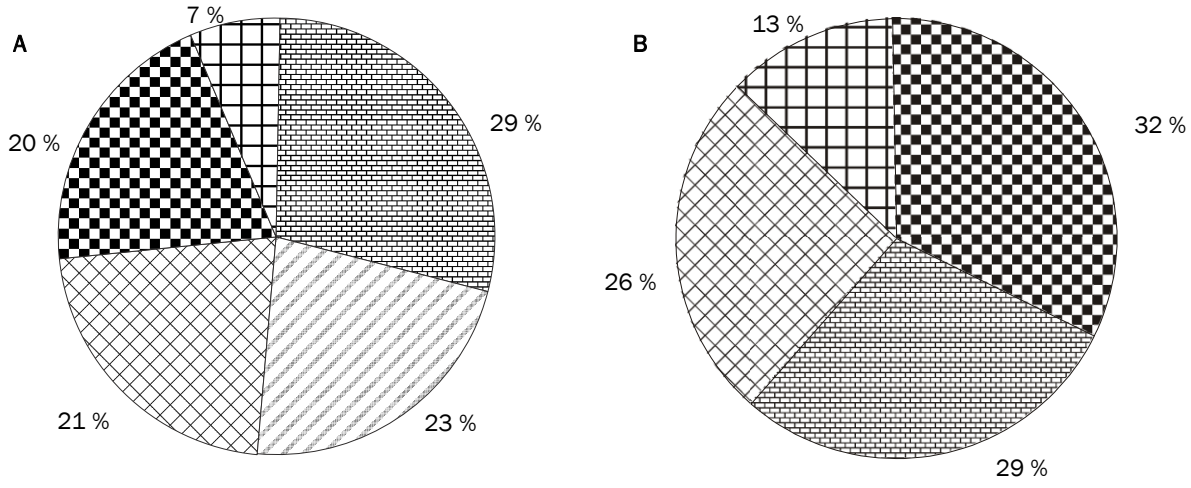

Figure 2. Bibliometric result of 1270 documents in marine biogeochemistry shows the Web of Science categories (a) and research areas (b)
Note : = Oceanography, = Geosciences multidisciplinary, = Marine freshwater biology, = Environmental sciences, = others

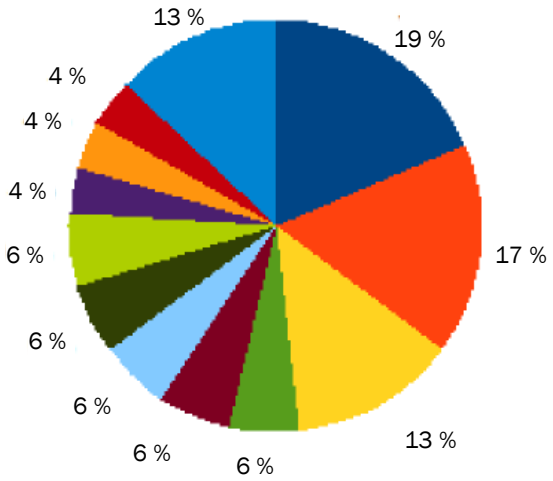

Figure 3. Research topics of RCO-LIPI (2010-2012)

Note : = Taxonomy, biodiversity, = Pollution, = Climate change, ocean acidification, = Biodiesel, = Primary production, = Fisheries cultivation product, = Environment assessment, = Coral reefs, = Carbon (Stock, flux and sources), = Bioactive, bioproduct, = Harmful algal bloom, = others

Organic matter and sediment are the leading topics in 2012, accounting for about 11.0% of 117 publications. Furthermore, dissolved organic matter seems to be the leading topic within this 11.0% (*e.g.* research by Cai *et al*., 2012; Fernanda-Adame *et al*., 2012, Huang *et al*, 2012; Li *et al*., 2012; Lutz *et al*., 2012; Man *et al*; 2012)).

Primary production and general biogeochemistry also became the trending topics in 2013. These two topics accounted for about 11.0% and 10.0% of 132 publications, respectively. Especially in the topic of primary production, some publications use modelling (*e.g.* Buitenhuis *et al*., 2013; Gilbert *et al*., 2013; Hirata *et al*., 2013).

As stated by Libes (2009), climate change, ocean acidification and global warming became important topics in the last decade and research about them was published in 5.6% of 107, 5.9% of 117 and 6.1% of 132 publications in 2011, 2012 and 2013, respectively. Although the total number of publication is not as high as that on many as other topics (*i.e.* microbial chemistry, sediment, organic matter or primary production) the topic of ocean acidification (related to climate change and global warming) is pursued by many researchers. For instance, if we input the term "effects of ocean acidification on marine ecosystem" (the topic is used by Hama *et al*. (2012) as the main topic in their project) in the Web of Science, there were 227 publications recorded from 1975 to January 2014. Furthermore, there will be more than two thousand publications when we input the keyword "ocean acidification".

Biogeochemistry research in South East Asia and surround

Biogeochemistry studies in SE Asian countries have been conducted in fresh and marine water. Some of the studies can be tracked down through international publications. However, some others may remain as local knowledge since they are only available in local or regional publications. Although the source is limited, it is still possible to find research in SE Asia in which the main focus is biogeochemistry.

One example is Jones *et al*. (2011) focused on the biogeochemistry of manganese in freshwater in Lake Matano (South Sulawesi, Indonesia). The lake is considered as a modern analogue to ferruginous oceans. Other research was conducted in fresh water (Brantas River, Indonesia) in correlation with the estuary and coastal waters of the Madura Strait (Indonesia). This research suggests that organic nitrogen may play an important role in coastal food webs and the nitrogen cycle in tropical regions. In the case study of the Brantas river estuary, it seems that fluvial nutrient and sediment input into the ocean is increasing as a result of human activities (Jennerjahn *et al*., 2004).

Biogeochemical processes in correlation with human activities have become an interesting topic of study in SE Asia. Biogeochemical cycles in Vietnamese coastal waters have been determined by both human activities which control material input from the land and hydrodynamics *e.g.* upwelling from the seas (An and Thu, 2007). A similar, though

smaller-scale study, was conducted in a lagoon (*i.e.* Segara Anakan, Java, Indonesia) by Jennerjahn *et al*. (2009). The study concludes that the lagoon biogeochemistry is affected by both anthropogenic activity and hydrodinamics. However, Jennerjahn *et al*. (2009) stated that natural processes still exert the major control over the nutrient inventory of the lagoon.

Other research by Waite *et al*. (2013) investigated the biogeochemistry of low dissolved oxygen high-nitrate (LDOHN) in the eastern Indian Ocean, off northwest Australia adjacent to Ningaloo Reef. The result indicates that LDOHN layers are formed from multiple subduction events of the Eastern Gyral Current beneath the Leeuwin Current (LC); the LC originates from both the Indonesian Throughflow (ITF) and the tropical Indian Ocean.

Topics related to particulate organic matter (POM) also get attention. Tue *et al*. (2012), for instance, studied the sources and exchange of particulate organic matter in an Estuarine mangrove ecosystem in Xuan Thuy National Park, Vietnam. The result suggested that the contribution of mangrove detritus to POM reaches a maximum at the low tide and is enhanced during the rainy season.

Two other studies in Vietnam are correlated with the biogeochemical role of benthic organisms. The first study is from Amano *et al.* (2011) who elucidated the contribution of anammox bacteria to Benthic Nitrogen cycling in a mangrove forest. Furthermore, this study provided new insight into the biogeography of anammox bacteria: `*Scalindua*' and `*Kuenenia*'-like species coexisted in the brackish sediment. The second study was conducted by Alongi *et al*. (1999) on benthic mineralization in the extensive shrimp ponds of the Mekong delta, Vietnam. The study showed the slow rates of benthic decomposition and the dominance of oxic and suboxic pathways reflect the slow rates of organic matter input, and phytoplankton and shrimp production in these extensive ponds.

More than a decade ago, seasonal and spatial variations in benthic metabolism and sulfur biogeochemistry were also studied in the Bangrong mangrove forest-seagrass bed system, Thailand. The study suggested that the oxidation processes control the pool sizes rather than the sulfate reduction rates (Holmer *et al*., 1999). Another research which Thailand (along with Indonesia, Malaysia, Cambodia) became a research area was about trace element exposure. As part of biogeochemical cycle of trace element, organisms's intake rates of some elements including Sn and Hg were analyzed (Agusa *et al*., 2007).

Palaeoceanograpy has also become a research topic of interest in SE Asia. As reported by Bin *et al*. (2009) who analyzed the diatom mats in Eastern Philippines Sea and identified the species of the diatoms as giant *Ethmodiscus rex* (Wallich) Hendey, blooms of which occurred during the last glacial periods. Diatoms were reported as the predominant contributors to global carbon fixation by accounting for over 40% of total oceanic primary production.

It seems that paleocenography is not the popular research topic since there were not many publication according to the SCI database which studied paleoceanography in SE Asia in the last five years.

However, two researches of elemental cycles were conducted in Bay of Bengal and Northern Indian Ocean. The first mentioned is about atmospheric pathways of phosphorous that dominantly contributed by anthropogenic sources such as fertilisers and biomass burning emissions (Srinivas and Sarin, 2012). Then, the second is about deposition of N. Fe and P which implicate to the C- and N-fixation (Srinivas and Sarin, 2013).

Others publication show researches about microbial activities were conducted in Papua New Guinea and New Zealand. Meyer-Dombard *et al.*, (2013) conducted research about microbial diversity and potential for arsenic and iron biogeochemical cycling in Papua New Guinea. Meanwhile, Ruff *et al.* (2013) compared the biogeochemistry and microbial communities of a variety of Hikurangi cold seep ecosystems in New Zealand.

The above discussion shows that the predominant topics of biogeochemical study in SE Asia are in sediment biogeochemistry (including anthropogenic issues, pollution, etc), element biogeochemistry, related to the carbon and nitrogen cycle, benthic-correlated biogeochemical process or even palaeoceanography.

Oceanography research in Indonesia

Oceanography research in Indonesia for last decades has been increasing in both quality and quantity. Beside the universities, there are two main institutes which conduct research in oceanography and marine science. Those institutes are the Research Center for Oceanography – Indonesian Institute for Sciences (RCO-LIPI) and Ministry of Maritime Affairs and Fisheries. The latter has some research centers such as the Institute for Marine Research and Observation.

According to the data from Implemented and Scheduled Research Program, the main research topics in RCO-LIPI in 2010-2012 were (RCO-LIPI, 2013): 1. Taxonomy and biodiversity; 2. Environmental assessment (including impact or ecology assessment); 3. Marine pollution; 4. Coral reefs assessment and conservation; 5. Climate change and ocean acidification; 6. Carbon source and flux; 7. Biodiesel (marine algae); 8. Bioactivity and bioproducts, etc.

Research topics in biodiversity, environment assessment and marine pollution were the leading topics. They account for about 19%, 17% and 13%, respectively, of the total number of research topics studied in the period 2010 to 2012 (Figure 3.). Research in biodiversity (and taxonomy) is the leading topic, since many new species have been found in Indonesia's marine waters. For example, using bibliometric analysis of the keywords, 'Crustacea', 'new species' and 'Indonesia', there are 134 documents (journals or proceedings) of which more than 60% were published in the last decade showing the identification of new species from Indonesia has increased in the last decade. Furthermore, according to (Wahyudi *et al*., 2010), from 1999 to 2010 there are 29 and 27 new species of marine crustacean and molluscs, respectively, which have been identified, an average of two new species per year, mostly crustaceans and molluscs. Although taxonomy and biodiversity have been the leading topics; biogeochemistry seems to be increasing as well. Biogeochemical methods and prespectives have become of interest for instance in environmental assessment and marine pollution or studies related to climate change and ocean acidification (See Figure 3.). This trend is expected to increase in the future, since interest in the commonly researched topics of climate change and ocean acidification is expected to continue to grow.

Research topics at the Institute for Marine Research and Observation - Ministry of Maritime Affairs and Fisheries (IMRO-KKP) show an almost similar trend to RCO LIPI. The research topics include coastal protection, carbon cycle and biogeochemistry, ocean acidification, climate change and coral reefs, conservation of coral reefs ecosystem, estuary ecosystem, marine dynamics and coastal ecosystem (BPOL-KKP, 2014).

The publication records sorted from SCI and SPCI-S show some topics correlated with oceanography research in Indonesia. Curiale *et al*. (2005) conducted paleoceanographic research about the isotopic and molecular characteristics of Miocene-reservoired oils in the Kutei Basin, Indonesia. Yulianto *et al*. (2004) studied Holocene environmental and mangrove dynamics showing that deposition at the study site in the Makassar Strait since the mid Holocene has been supra-tidal terrestrial (fluvia/floodplain). Other researchers are interested in biodiversity, *e.g.* Last *et al*. (2006) who discovered a new species of whipray (Myliobatiformes: Dasyatidae) from Irian Jaya (now Papua), and Liao *et al*. (2004) who recorded macrobenthic marine algae and seagrasses of the Anambas Expedition in 2002.

Indonesia and future research in marine biogeochemistry

Based on the trends in marine biogeochemistry research worldwide, this discussion turns to projected research in Indonesia for the next decades. The effect of global warming will be a significant research topic, especially related to the coral reefs or mangrove ecosystem. The effect of ocean acidification in primary production or benthic organisms is also likely to become a major topic in the near future. Shifts in species distribution as an effect of ocean acidification or the rise of water temperature are likely research topics too. The biogeochemical role of certain species in organic material transfer is also likely to be a topic of future research. Furthermore, researches related to elemental cycle (*e.g.* carbon or nitrogen cycle) are likely interesting topics which directly correlated to biogeochemistry. Thus, research such as blue carbon (including carbon storage, sequestration and flux) will be more incisive and comprehensive when biogeochemistry point of views is used.

Marine pollution and sediment have become regular research topics (Figure 3.) and using biogeochemical methods is expected to lead to new breakthroughs. Although primary production has been studied extensively, it will get more attention because of the dynamics of oceanography in Indonesia, especially if linked to global climate change. Topics in paleoceanography may also become an important research area, for example, research about the Indonesian through flow (ITF) in the past and its effects on the regional climate or heat transfer.

Possibility in dealing with obstacles

Research in biogeochemistry will not be named as one of the seven research focuses according to National Research Agenda (NRA). The NRA will be focused on food security, energy, informatics and communication technology, transportation, defense, health and medicine technology, and advanced materials (Figure 4). However, as stated in the NRA, basic science, including earth and space science (biogeochemistry is included), will also be strengthened as the foundation of the technology and advanced science.

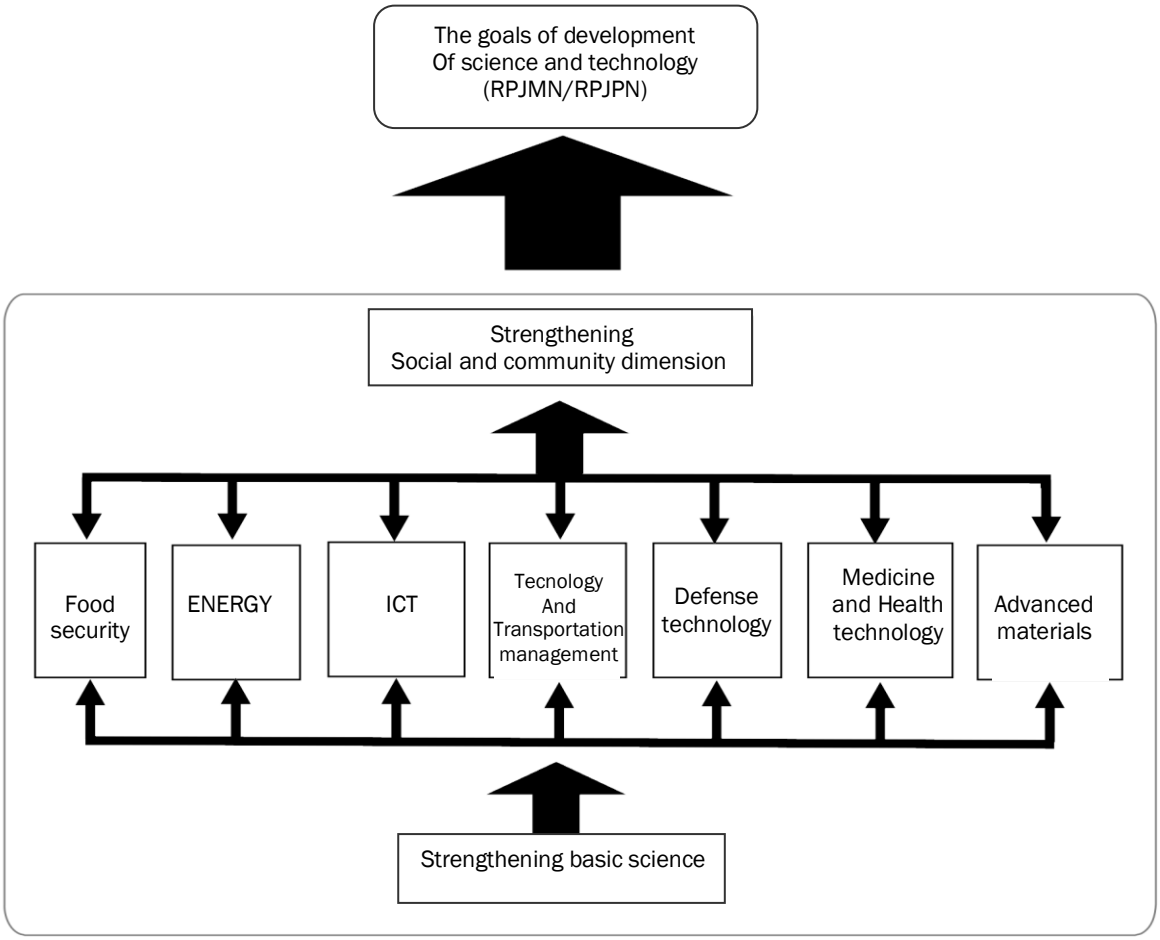

Figure 4. The correlation between the focus area and supporting factors for the development of science and technology according to National Research Agenda of Republic of Indonesia. RPJMN: The National Medium Term Development Plan; RPJPN: The National Long Term Development Plan; ICT: Information and Communication Technology. Adapted from National Research Agenda of Republic of Indonesia 2010-2014.

Furthermore, it is stated that "*Research in the field of earth and space science is directed to achieve the target formulation in development and discovery natural phenomena of environment (earth, sea and space). This target includes the development and mastery of knowledge related to the marine resources and innovation system, weather and climate change, the rate of increase in sea water as well as development of tsunami early warning systems, earthquake, and precursor studies.*" (State Ministry of Research and Technology, 2010) Marine biogeochemistry research in Indonesia may face some constraints in budget and equipment. For instance isotopic analysis cannot be performed independently in Indonesia. Therefore, in order to conduct such research, joint research with a foreign research institute is required.

First, it is important to determine the existing resources such as tools and equipment and related institutions such as research institutes and universities in Indonesia and overseas. This step can help the researcher to determine the possibilities for joint research. Recently, there are many research grants available from the Indonesian government or foreign funding agencies and Indonesian researchers should be prepared to compete for those grants. Though those grants are not large, they can still be useful.

Conclusion

According to bibliometric analysis, the research trends in marine biogeochemistry include topics such as 1) microbial ecology and the role in biogeochemistry, 2) organic matter and sediment, 3) climate change, ocean acidification and global warming, 4) primary production and general biogeochemistry. The effect of global warming on ecosystems (especially mangrove and coral reefs), the effect of ocean acidification in primary production or on benthic organisms, species distribution shift and the biogeochemical role of

certain species in organic material transfer, elemental cycles (including carbon cycle) are predicted to be the main topics of marine biogeochemistry in Indonesia over the next decades. Therefore, it is clear that the relatively new discipline of biogeochemistry must be an essential part of any comprehensive study of marine science, especially in significant areas such as global climate change and ocean acidification.

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