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Forest Bioeconomy and Sustainable Development Goals*

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Abstract: The global society developed the idea a "bioeconomy" in which technological solutions are used to solve resource-based problems facing the world. Green biotechnology focused on agriculture and forestry is central to the idea of a bioeconomy and has garnered much attention. The purpose of this study was to analyze the global discourse on the role of forests within the bioeconomy. Content analysis was applied in this study for analyzing international academic articles on the subject. The research findings indicated the creation of scientific discourse on the forest bioeconomy. The dominant approach to and contribution of a forest bioeconomy to the "Sustainable Development Goals" (SDGs) of the United Nations Development Programme (UNDP), as part of a global vision, were analyzed. As a result, this research indicates the dominant keywords of the scientific discourse on the forest bioeconomy: biomass, bioenergy, sustainability, policy, and life cycle assessment. An examination of the links between the forest bioeconomy and the UNDP SDGs was also undertaken including analysis of the SDG goals of clean energy (SDG 7), sustainable industry and infrastructure (SDG 9), sustainable production and consumption (SDG 12), and climate change mitigation (SDG 13).
Key Words: Bioeconomy, Forest, Biotechnology, Sustainable Development Goals

I. Introduction

Biomass is regarded as a renewable resource at the society which faces complex problems including energy, climate change, pollution and so on. Biomass refers to "organic products and wastes and residues from agriculture, forestry, and other sources including

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fisheries and aquaculture (Müller et al., 2015, p.5)." Biomass has a potential to replace fossil fuels and materials. It can be converted to bio-products for producing energy, animal feed and chemicals. Recognized the high values and potential of biomass, bio-based economy, namely bioeconomy was created. Bioeconomy is defined as "an economy where the basic blocks for materials, chemicals and energy are derived from renewable biological resources, such as plant and animal sources (McCormick and Kautto, 2013, p.2590)." European Commission established a strategy and action plan called 'Innovation for Sustainable Growth: A Bioeconomy for Europe' in 2012, highlighting investments in research, innovation and skills, reinforcement of policy interaction and stakeholder engagement, and enhancement of markets and competitiveness in the bioeconomy sectors (de Besi and McCormick, 2015, p.10462). The EU Renewable Energy Directive (EU Directive 2009/28/EC, 2009) sets a target of increasing the share of renewable energy use in the EU from 8.5% in 2005 to 20% by 2020 in order to limit greenhouse gas emissions and to promote cleaner transport (Lind et al., 2013, p.364). Bioeconomy is at the heart of the European Commission's investment agenda. Supported by the right policy framework, investment in the bioeconomy could add 0.43% of additional EU GDP, as well as 436.000 additional jobs by 2025 (European Commission, 2015).

Global society regards bioeconomy as technological solutions to resource-based problems which the world faces. The Organisation for Economic Cooperation and Development (OECD), the EU and several EU member countries such as Germany and Finland have established policy strategies to support bioeconomy (Borgström, 2018). In particular, green biotechnology focused on agriculture and forestry as

a main sector of bioeconomy is paid much attentions.

Recently the bioeconomy research emerged in the forestry sector. Research on bioeconomy and forestry includes multiple issues such as forest-based bioenergy (McCormick and Kautto, 2013) and wood plastic composites (Sommerhuber et al., 2017). Kleinschmit et al. (2014) examined diverse disciplinary perspectives on the forestry sector in a bioeconomy such as policy analysis, economics and business administration disciplines. However, previous researches have not analyzed science discourse on forest and bioeconomy.

The purpose of this study is to analyze global discourse on bioeconomy in the forest science. In the second section, this study identifies and compares three economies towards sustainable development - green economy, circular economy and bioeconomy. It follows the concept of bioeconomy focusing on resource efficiency. In the third section, the paper presents history and contents of sustainable development goals. In the fourth section, this study describes content analysis as a research methodology. In the fifth section, it analyzes the number and resources of international academic articles on 'forest bioeconomy' and interprets the keywords and their linkage with sustainable development goals. Finally, conclusions are drawn in the sixth section.

Ⅱ. Three Economies towards Sustainable Development

Three types of economy are identified to achieve sustainable development; green economy, circular economy and bioeconomy.

Here three economies are described and compared.

1. Green Economy

Green economy highlights low-carbon, resource efficient and socially inclusive. In Rio +20 conference in 2012, 'green economy' was adopted as a core agenda in the context of sustainable development and poverty eradication. UNEP (2011, p.2) defines "a green economy as one that results in improved human well-being and social equity, while significantly reducing environmental risks and ecological scarcities". Greening of ten central sectors is highlighted as driving the transition to a green economy; agriculture, fisheries, water, forests, renewable energy, manufacturing, waste, building, transport and tourism (〈Figure 1〉) (UNEP, 2011). Green economy brings several countries to green growth and low carbon economic strategies. As a natural capital, the sectors of agriculture and forestry offer primary production and have impact to the livelihoods of the people. However, deforestation threatens forest ecosystem services. New market-based mechanism was introduced to certify forest products and to pay for ecosystem services, such as, Forest Stewardship Council certification and REDD+ (Reducing Emissions from Deforestation and Forest Degradation and enhancing conservation, sustainable management of forests, and forest carbon stocks). Forest plays a role in a green economy through providing timber products, non-timber forest products and ecological infrastructure. It contributes to increasing livelihood and forest quality.

〈Figure 1〉 10 Sectors of green economy

2. Circular Economy

The concept of circular economy emerged in the late 1970s (Geissdoerfer et al., 2017). Circular economy is defined as "a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops. This can be achieved through long-lasting design, maintenance, repair, reuse, remanufacturing, refurbishing and recycling (Geissdoerfer et al., 2017, p.759)." It has a focus on inputs and outputs of production and consumption in the industrial process. It emphasizes waste reduction and resource efficiency considering life cycles (Husgafvel et al., 2018). Within the circular economy, forestry can contribute to improve materials recovery and resource efficiency through cascading of wood and paper byproducts and recycling lumber from construction (Husgafvel et al., 2018, p.484). Recycling and circulating wood materials can be assessed with life cycle assessment (LCA) focusing on efficiency of resource utilization (Sommerhuber et al., 2017).

3. Bioeconomy

Bioeconomy offers technological solutions for many challenges facing the world through biotechnology. Bioeconomy pursues economic outputs through biotechnology towards sustainable development. Biotechnology is the application of science and technology to living organisms, as well as parts, products and models thereof, to alter living or non-living materials for production of knowledge, goods and services (OECD, 2001). There are three main sectors where biotechnology can be applied: agriculture, health and industry (OECD, 2009, p.8). The sectors can be classified with three colors. Red and white biotechnology is applied to the health and industrial sector respectively and green biotechnology is applied to the agriculture sector and the forestry sector (Da Silva et al., 2004). Forest or wood-based bioeconomy includes production of bioenergy with innovative biorefinery technologies using wood resources. Biorefinery (McCormick and Kautto, 2013) can contribute to producing alternative resources and increasing market benefits of wood resources.

4. Comparison of Tree Economies in the Forestry Sector

Towards sustainable development, three economies emerged. Each economy has different focuses (〈Table 1〉). Green economy functions as an 'umbrella' concept, including elements from circular economy and bioeconomy concepts (D'Amato et al., 2017). In green economy, forestry sector generally has an opportunity to create new green jobs and market opportunities, comparing traditional forestry. Circular economy and bioeconomy have focus on resource. In circular

economy, efficiency of forest resources is highlighted in the LCA. In bioeconomy, forest-based biotechnology is developed and new resources like biofuels are created. Bioeconomy can accept the general concept and directions of green economy. In practice, circular economy and bioeconomy approaches in the forestry sector can contribute to enhancing quality of human life through increasing forest resource efficiency and creating alternative resources. This article focuses on forest-based bioeconomy including biomass, renewables and biotechnology.

〈Table 1〉 Comparing green economy, circular economy and bioeconomy

Types of economy	Main topic	Research field
Green economy	Sustainable Development, green investment, biomass and renewables, recycling and conservation	Environmental or ecological economics
Circular economy	Sustainable Development in industrialization, efficiency, recycling, supply chain and urbanization	Industrial ecology
Bioeconomy	Biomass, renewables, biotechnology and rural development	Technology

[Source] D'Amato et al. (2017)

Ⅲ. Sustainable Development Goals[1)]

The global community set sustainable development as a goal for present and future generations at the United Nations Conference on Environment and Development (UNCED), which was held in Rio de Janeiro in 1992. Sustainable development is "a process of change in

1) This chapter includes the original text of the sub-chapter 2.1.2 'Sustainable Development Goals' from the technical report, 'Eco-innovation and sustainable consumption and production in Vietnam (Park et al., 2017, pp.13-15)'.

which the exploitation of resources, the direction of investments, the orientation of technological development, and institutional change are all in harmony and enhance both current and future potential to meet human needs and aspirations (World Commission on Environment and Development, 1987)". Rio's Declaration on Environment and Development was agreed upon by 108 states. The 2002 World Summit on Sustainable Development advanced the mainstreaming of the three dimensions of sustainable development in development policies at all levels through the adoption of the Johannesburg Plan of Implementation (JPOI). At the Rio+20 Conference in 2012, the international community decided to launch a process to develop a set of Sustainable Development Goals (SDGs), which were to build upon the Millennium Development Goals (MDGs) and converge with the post 2015 development agenda. On 25 September 2015, the United Nations General Assembly formally adopted the universal, integrated and transformative 2030 Agenda for Sustainable Development, along with a set of 17 SDGs and 169 targets.

The global society adopted the United Nations Millennium Declaration at the Millennium Summit in New York in 2000. They set out a series of eight time-bound targets – with a deadline of 2015 – that have become known as the MDGs. MDG targets include the goals of eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality and empowering women, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases, ensuring environmental sustainability and developing a global partnership for development (〈Table 2〉). SDGs address the multiple interlinked global challenges of eradicating poverty,

ensuring environmental sustainability, achieving economic equity, ensuring gender equality, tackling climate change, building resilience, managing equitable distribution of natural resources, realizing human rights, and reducing inequality between and within populations. SDGs have similarity with MDGs. However, there are some key differences between MDGs and SDGs. SDGs are more expansive with a clear acknowledgement that include the multiple targets than MDGs. Environmental dimensions and their interconnection with different problems are even more emphasized in the SDGs than in the MDGs (Stevens and Kanie, 2016). The SDGs might have an integrative approach that includes Earth's life-support system and poverty reduction (Griggs et al., 2013). The shift from MDGs to SDGs indicates the expansion of the spaces where development should happen (Willis, 2016). Most of target countries of MDGs are the Global South. MDGs specify a basic service delivery and absolute poverty as a baseline. On the other hand, SDGs are more inclusive in an understanding of where sustainable development should take place (Willis, 2016). Achievement of SDGs requires efforts from both the Global North and South. The levels of targets are identified with the basis of an understanding of the values at the individual contexts. Within SDGs the target countries are both the Global North and South. In addition SDGs were initiated through open and transparent communication process among multiple sectors, while MDGs were formed by internal UN actors (Stevens and Kanie, 2016). SDGs are the shared goals through deliberative discussion at the global society. Therefore, SDGs are an output of global governance.

〈Table 2〉 MDGs and SDGs

Type of goals	Goal No.	Content
Millennium development goals (8)	Goal 1	Eradicate extreme poverty and hunger
	Goal 2	Achieve universal primary education
	Goal 3	Promote gender equality and empower women
	Goal 4	Reduce child mortality
	Goal 5	Improve maternal health
	Goal 6	Combat HIV/AIDS, malaria and other diseases
	Goal 7	Ensure environmental sustainability
	Goal 8	Develop a global partnership for development
Sustainable development goals (17)	Goal 1	End poverty in all its forms everywhere
	Goal 2	End hunger, achieve food security and improved nutrition and promote sustainable agriculture
	Goal 3	Ensure healthy lives and promote well-being for all at all ages
	Goal 4	Ensure inclusive and equitable education and promote lifelong learning opportunities for all
	Goal 5	Achieve gender equality and empower all women and girls
	Goal 6	Ensure availability and sustainable management of water and sanitation for all
	Goal 7	Ensure access to affordable, reliable, sustainable and modern energy for all
	Goal 8	Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all
	Goal 9	Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation
	Goal 10	Reduce inequality within and among countries
	Goal 11	Make cities and human settlements inclusive, safe, resilient and sustainable
	Goal 12	Ensure sustainable consumption and production patterns
	Goal 13	Take urgent action to combat climate change and its impacts
	Goal 14	Conserve and sustainably use the oceans, seas and marine resources for sustainable development
	Goal 15	Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably mange forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss
	Goal 16	Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels
	Goal 17	Strengthen the means of implementation and revitalize the global partnership for sustainable development

Ⅳ. Research Design

In this study, quantitative content analysis methodology was used to understand science and policy discourse on bioeconomy in forestry sector. Content analysis is a method of elevating social reality and shows a manifest text and latent context (Merten, 1995). Content analysis has a diagnostic function in situations where the content is produced and a prognostic function regarding further treatment of content sources (Atteslander, 1991). Content analysis helps to grasp reality through depiction of real life, and the described contents stimulate new research academically. In this study, content analysis methodology is applied to describe science discourse on forest bioeconomy.

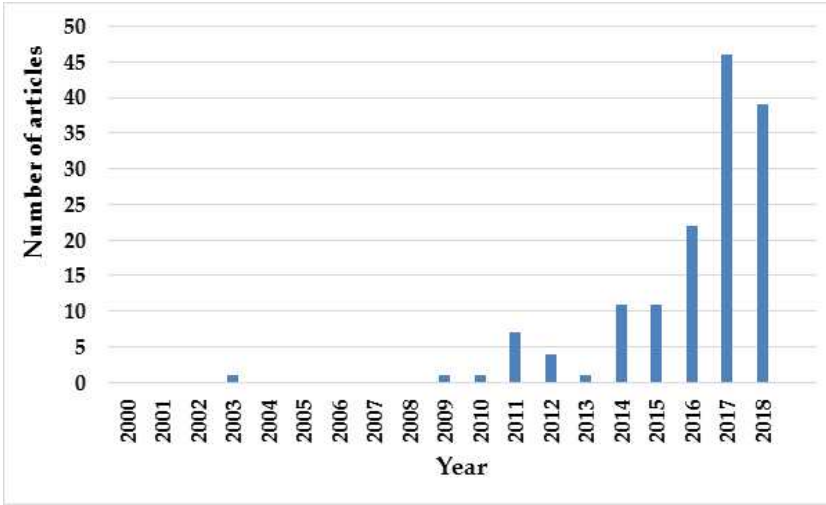
Scientific papers were analyzed to understand science discourse. In order to grasp the global science discourse, academic papers containing the words 'bioeconomy' and 'forest' or 'wood' in title, keyword, and abstract were extracted through the international specialized academic database, SCOPUS. The period covered is from January 1, 2000 to July 31, 2018. Analysis items are the year of publication, keyword and published journal title. A total of 186 papers were retrieved from SCOPUS with the above method. A total of 144 papers were selected for the analysis, excluding the articles which include the term of bioeconomy but no interpretation of bioeconomy in the abstract. The dominant keywords and linkage between keywords and SDGs were analyzed.

V. Research Results and Discussion

1. Number of Articles

The Figure 2 on distribution of the academic papers by year shows that the papers on forest bioeconomy started to be published from the late 2000s and increased since the year 2014. Introduction of bioeconomy policies might influence the increase of the number of articles on forest bioeconomy. In this research the collected articles in 2018 are the article published until July 31, 2018. It is expected that the total number of articles until the end of the year 2018 might be more than the last year 2017.

〈Figure 2〉 The number of articles on forest bioeconomy published at the international journals (N=144)



2. Source of the Articles

The selected articles were published from 88 international journals.

The Journal of Cleaner Production published the most articles (17 articles) on forest bioeconomy (〈Table 3〉). *The Journal of Cleaner Production* focuses on cleaner production aims at preventing the production of waste, while increasing efficiencies in the uses of energy, water, resources, and human capital. It has a dominant approach to industrial development and innovation emphasizing cleaner production. The articles on forest bioeconomy from *the Journal of Cleaner Production* include various aspects including climate mitigation effects of new construction using wood-based materials (Peñaloza et al., 2018) and wood product cascading (Bais-Moleman et al., 2018), inclusion of citizens in bioeconomy (Mustalahti, 2018), biorefineries (Giurca and Späth, 2017; Hagman et al., 2018) and input-output analysis of wood use (Budzinski et al., 2017). *Scandinavian Journal of Forest Research* published 13 articles on forest bioeconomy. *Scandinavian Journal of Forest Research* as a forest science journal paid special attention to forest bioeconomy. The journal published two special issues; "Biobased Economy" in 2014 (volume 29, issue 4) and "Towards a Sustainable Bioeconomy (volume 32, issue 7) in 2017. Next to *the Scandinavian Journal of Forest Research, the journals of Forest Policy* and Economics, *Forests, Forest Chronicle and Biofuels* published several articles on bioeconomy. Over half of total articles were distributed to different journals including forest related journal such as, *Sustainable Forestry, International Forestry Review* and Forest Economics and biotechnology related journals such as *New Biotechnology, Biomass and Bioenergy and Biotechnology Advances*.

〈Table 3〉 Number of articles by sources title

N=144

Source title (Top 6)	Number of articles
Journal of cleaner production	17
Scandinavian journal of forest research	13
Forest policy and economics	7
Forests	6
Forestry chronicle	6
Biofuels	4

3. Keywords

The keywords presented by authors in each article were collected. 19 of the 144 articles, did not provide the keywords. A total of 125 papers were analyzed, and a total of 623 keywords were identified. The total number of words mentioned just once is 446, and the number of words mentioned twice is 84. The most commonly used words are shown in the Table 3 below.

The word 'bioeconomy' is the most commonly mentioned word as keywords of the articles. Next, ‘forest/ry’ and ‘wood/y’ were most frequently mentioned as keywords. Since these three words were used as the searching keywords in the process of extracting the paper according to the research methodology, it is a natural result to be frequently mentioned as keywords. Therefore, this study intends to focus on the main words excluding the bioeconomy, forest (forestry), and wood (woody). Looking at the most commonly mentioned keywords after the three words presented above, biomass, bioenergy, sustainability, policy and life cycle assessment (combination of life, cycle and assessment) are frequently presented (〈Table 4〉).

〈Table 4〉 Top 30 frequency of keywords in the selected articles

Keyword	Frequency	Keyword	Frequency	Keyword	Frequency
Bioeconomy	73	management	11	supply	7
Forest/ry	71	social	10	sector	7
(Bio)Energy	31	products	11	timber	7
Biomass	28	life	9	carbon	7
Wood/y	28	cycle	9	bio	7
Sustainable/-bility	17	assessment	9	industry	6
Analysis	14	innovation(s)	9	decision	6
Economy	13	Germany	8	climate	6
Based	13	biorefinery	8	waste	5
Policy/-ies	13	use	7	value	5

1) Biomass/Bioenergy

According to OECD (2009, p.8), bioeconomy has three elements: 1) the use of advanced knowledge of genes and complex cell processes to develop new processes and products, 2) the use of renewable biomass and efficient bioprocesses to support sustainable production, and 3) the integration of biotechnology knowledge and application across sectors. Biotechnology can induce sectoral innovation using renewable resources. In forest bioeconomy, values of biomass as renewable resources are emphasized. Biomass is regarded a vital source for the future global energy supply. Forest biomass is a potentially major source of biomass for energy (Berndes et al., 2003). Social demand emerged in transforming non-food biomass into biodiesel production. Wood-based biomass can be used for energy production. Wood-based biomass has two types; primary biomass produced from forests and secondary biomass resulting from the processing of primary biomass (Carneiro and Ferreira, 2012). The principal products of the bioeconomy are bio-based products and

bioenergy, while the fundamental technology is known as biorefineries (McCormick and Kautto, 2013). The biorefinery concept is defined as "the sustainable processing of biomass into a spectrum of marketable products (food, feed, materials and chemicals) and energy (fuels, power and heat) (McCormick and Kautto, 2013, p.2594)." Biorefinery can be a new business model OECD (2009, p.13). The use of phytochemicals from waste residues obtained from the poplar wood industry can generate additional revenue and contribute to the bioeconomy (Devappa et al., 2015). To transition to an advanced bioeconomy, the potential implementation of biorefining was assessed based on the existing forestry infrastructure and available forest fiber in Canada (Blair et al., 2017). Biorefinery development relies on the advancement in technology of a range of process and is related to the huge demand for biomass associated to large capacity needed to become cost effective (Scarlat et al., 2015).

2) Policy

Policy is one of the most mentioned keywords. Some articles analyzed regional, national and local policies on forest bioeconomy including Europe (Scarlat et al., 2015), Germany (Purkus et al., 2018), Finland (Kröger and Raitio, 2017) and Ontario, Canada (Majumdar et al., 2017). To foster forest bioeconomy, integrated approach with other sectors (Majumdar et al., 2017), challenges and opportunities of bio-based products and policy instruments including labelling (Scarlat et al., 2015) were recommended. Discourse on bioeconomy represented in academic articles shows dominantly economic aspect and neglects social considerations (Pülzl et al., 2014). In particular, policies and strategies on forest bioeconomy were introduced more in Germany

(Pannicke et al., 2015; Giurca and Späth, 2017; Purkus et al., 2018; Hagman et al., 2018) than other countries.

3) Life Cycle Assessment

Life cycle assessment (LCA) is a tool to assess environmental impacts with a process (Klavina et al., 2017). In practice, LCA is used to compare the environmental impact of two alternative woodchip use scenarios: heat and power production from woodchips in a woodchip combined heat and power production woodchip pyrolysis where the produced biochar is pelletized (Klavina et al., 2017). LCA was applied to assess wood plastic composites from wood particles (Sommerhuber et al., 2017) and climate mitigation effects of increasing the use of wood materials in the construction of new residential dwellings (Peñaloza et al., 2018). Siebert et al. (2018) developed social life cycle assessment indices and indicators to monitor the social implications of wood-based products in Germany. LCA approach contributes to circular economy emphasizing waste reduction and resource efficiency (Husgafvel et al., 2018).

4) Sustainability

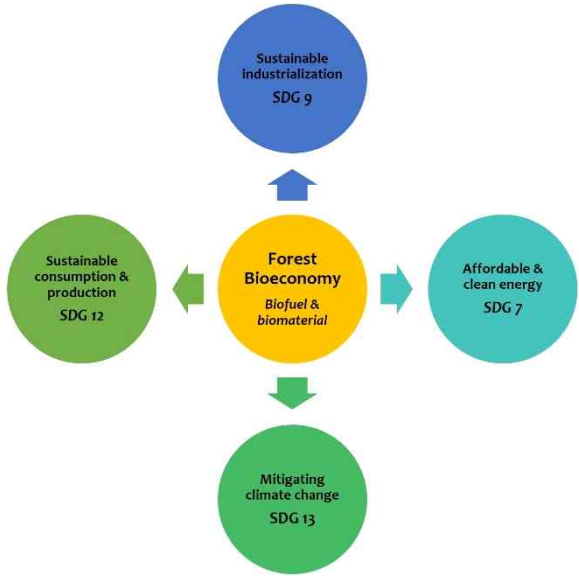
Sustainability has been accepted as a guideline of forest management at the global society. As the Forest Principles (UN, 1992) show sustainable forest management is a shared goal of forest management. Forest bioeconomy has also a direction towards sustainability. Wood is regarded as biomass for sustainable energy production (Dal Poz et al., 2017; Cavicchi et al., 2017). Forest bioeconomy is oriented to sustainable bioeconomy through

sustainable pathways of industrial production (Hagemann et al., 2016). Forest biotechnology can be regarded as a new means to achieve sustainable development in the forestry. It has great potential to create and develop new and more sustainable industries by optimizing the use of forest resources.

4. Forest Bioeconomy and Sustainable Development Goals

SDGs require sectoral approach including forestry. Here contribution of forest bioeconomy focusing on forest biotechnology to achieving SDGs is explored (〈Figure 3〉). Forest biotechnology transforms wood-based biomass to energy source such as biofuels and biomaterials such as wood plastic composites (Sommerhuber et al., 2017). It contributes to realizing resilient infrastructure, inclusive and sustainable industrialization and innovation (SDG 9). In particular wood-based biofuels produce energy and consequently contribute to achieving affordable and clean energy (SDG 7). With forest biotechnology, wood wastes or residuals from forest management activities can be used as resources for other products. The forest biotechnology fosters a sustainable biomass supply with increasing productivities and creating new supply chains and markets for bio-based products. Consequently, it contributes to sustainable consumption and production patterns (SDG 12). The use of wood-based materials instead of other materials like concrete in the construction of building contributes to mitigating climate change (SDG 13).

〈Figure 3〉 Forest bioeconomy and sustainable development goals



Ⅵ. Conclusion

Under the background of increasing global policies and researches on bioeconomy, this research focuses on science discourse on forest bioeconomy in the international academic journals. This research indicates the dominant keywords of science discourse on forest bioeconomy: biomass, (bio)energy, policy, sustainability and LCA. The keywords help our understanding of forest bioeconomy. Forest bioeconomy is based on forest biotechnology using biomass and producing energy and alternative products. LCA presents resource efficiency of wood-based energy and materials and supports validity of forest bioeconomy. Forest bioeconomy has been realized and facilitated by regional and national policies towards sustainability and sustainable development. Therefore, the keywords are explicitly

linked with the SDGs including clean energy (SDG 7), sustainable industry and infrastructure (SDG 9), sustainable production and consumption (SDG 12) and climate change mitigation (SDG 13).

This research provides simple information on key terms of forest bioeconomy. However, the analysis of science discourse on forest bioeconomy can contribute to understanding the global research trends. The results of this study can be applied to the design of forest bioeconomy researches and policies by demonstrating the challenges and opportunities of forest bioeconomy.

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