Tri Harso Karyono · Robert Vale
Brenda Vale *Editors*

Sustainable Building and Built Environments to Mitigate Climate Change in the Tropics

Conceptual and Practical Approaches

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Editors
Tri Harso Karyono
School of Architecture
Tanri Abeng University
Jakarta, Indonesia

Robert Vale
School of Architecture and Design
Victoria University of Wellington
Wellington, New Zealand

Brenda Vale
School of Architecture and Design
Victoria University of Wellington
Wellington, New Zealand

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Preface

This book is about presenting solutions to problems of the built environment due to the current changes of the world climate. A number of efforts have been made in different parts of the world to attempt to minimize it. This book presents some conceptual and practical approaches to respond to this phenomenon with a particular focus on the tropics.

The book is a compilation of selected articles presented in the 2015 Tanri Abeng University Conference in Jakarta, Indonesia. This international conference was organized jointly by the School of Architecture, Tanri Abeng University, Indonesia; London Metropolitan University; England, and Heriot-Watt University, Scotland.

Seventeen articles have been selected as chapters which are grouped into four parts to form the book. The first part of this book deals with the general issue of climate change. It discusses the causes and the ways of mitigation and adaptation of the built environment to climate change. This first part discusses the development of some developing countries, such as Indonesia, in which improving a nation's well-being would need a massive development of the nation's infrastructure and its built environment. The massive developments of infrastructure and the built environment have triggered the use of fossil fuel and other earth's resources, emitting huge amounts of carbon dioxide, creating global warming and climate change. Some conceptual strategies to overcome these problems are discussed in this part. The concept of sustainability, in which reducing carbon emissions was seen as likely to be the only way to reduce global warming, is challenged. The renewable energy sources, which emit low carbon, are still demanding land to generate the energy, raising the ecological footprint. There are articles in this part that discuss the way to mitigate climate change in non-tropical climates, and these can be used as a comparative study for a tropical case.

The second part of this book offers articles that examine the way to overcome disasters in the city caused by climate change. The Indonesian capital city of Jakarta has suffered from frequent floods, creating problems not only for the fishing settlements in the coastal areas but also for those living in the centre of the city. Some proposed strategies to overcome these problems are discussed in this part. The way to reduce the urban heat island (UHI) effect in the urban areas is also discussed in

this chapter. It deals with the Singaporean problems of land being covered mainly by hard surface materials across the country. Along with the problems of flood, Jakarta is also suffering from traffic congestion, creating air pollution in the capital city. In this part, a bicycle lane system is proposed to improve the air quality and at the same time reduce the traffic congestion and the carbon emissions in this city.

The third part of the book deals with some practical approaches to make buildings that can help to mitigate climate change by reducing their need for nonrenewable energy. It proposes ways to reduce cooling energy by means of passive design in tropical buildings, such as in Malaysia. Examples are given of how buildings can be designed in such a way that solar heat gain is kept to a minimum, to create low indoor temperatures with a minimum help from mechanical means, thus reducing building energy consumption and promoting low-carbon buildings.

The last part of the book deals with the role of plants in mitigating and adapting the built environment to climate change. The impacts of plants as vertical and rooftop gardens to reduce the adjacent outdoor temperature as well as the indoor temperature in Singapore are discussed in this part along with the use of banana fibre as a possible source of building materials in Brazil.

I would like to thank all of the contributors who submitted their articles compiled in this book. Gratitude is given to Springer, the publisher which kindly publishes this book. I would also like to thank Fergus Nicol and Sue Roaf for their efforts to invite authors to submit their articles in our successful conference.

Jakarta, Indonesia Tri Harso Karyono

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About the Editors

Professor Tri Harso Karyono
Tri was trained as an architect at the Department of Architecture, Bandung Institute of Technology (ITB), Indonesia, from which he received an engineering degree (Ir.) in architecture. He received a master's degree (MA) in architecture from the University of York, England, following the completion of his dissertation on "Solar Energy and Architecture: A Study of Passive Solar Design for Hospital Wards in Indonesia". Tri was awarded a doctorate (PhD) from the School of Architectural Studies, University of Sheffield, England, after finishing his thesis on "Thermal comfort and energy studies in multi-story office buildings in Jakarta, Indonesia".

Teaching in a number of architectural schools in Jakarta and also acting as doctoral external examiner at various universities, he has published a number of books on sustainable built environment and tropical architecture. His book on green architecture (in Bahasa Indonesia) (2010) has been reprinted three times within 6 years of publication. His latest book *Tropical Architecture: Form, Technology, Comfort and Energy Use* (in Bahasa Indonesia) (2016) tries to reposition the term of tropical architecture, which has been misinterpreted by many Indonesian scholars as a vernacular architecture. Tri has also been publishing a number of scientific articles, particularly related to thermal comfort in the warm and humid tropical climate in a number of international journals. He has published numerous articles in a number of Indonesian newspapers and architectural magazines. He designed his low-energy house at the outskirts of Jakarta in 2007. This house consumes very little electricity and is fairly comfortable without air conditioning.

Tri was awarded a professorship by the Indonesian Ministry of Education in 2007 and presented his inaugural lecture entitled "From Thermal Comfort to Global Warming: Architecture and Energy Points of View". His research interests are in the fields of thermal comfort, tropical architecture, sustainable built environment and low-carbon town.

Professor Robert Vale and Professor Brenda Vale

Robert Vale and Brenda Vale are architects and academics who studied architecture together at the University of Cambridge and wrote their first book on sustainable design, *The Autonomous House*, in 1975. Following their design of several award-winning buildings for the National Health Service in the UK, they built the UK's first autonomous house in 1993 and the first zero-emissions settlement, the Hockerton Housing Project, in 1998. It was the analysis of the performance of these buildings that revealed the importance of behaviour and led to their current research into ecological footprints, using the concept initially devised by Wackernagel and Rees in Canada in the 1990s.

The Vales have received a number of international awards, including those from the United Nations and the European Solar Energy Society, for their work. They carried out the initial development of the Australian government's National Australian Built Environment Rating System (NABERS) which has now been put into operation. Their 2009 book, *Time to Eat the Dog? The Real Guide to Sustainable Living*, used the ecological footprint to look at the environmental impact of how we live today, including the impact of household pets. Their surprising finding, subsequently supported by other researchers, was that a big dog in a western country has a similar impact to that of a person in Indonesia. More recently, they edited a book called *Living Within a Fair-Share Ecological Footprint* which comprised a series of studies written by colleagues, former students and current postgraduates. They are currently collaborating on a book that compares the ecological footprint of daily living around the world. Their areas of research at present are in the fields of sustainability, resilience, building materials and architectural history.

Chapter 1
Introduction: The Tropics: A Region Defined by Climate

Robert Vale and Brenda Vale

Abstract The Tropics is a region defined by geography rather than by political boundaries. This makes it a region also defined by climate. Global climate is changing as a result of greenhouse gas emissions from human activities. Temperature increases as a consequence of climate change are likely to be most severe in the Tropics, a region which is home to 40% of the global population, but produces only 15% of the world's greenhouse gas emissions. This book provides a wide range of examples that have been proposed by researchers to show the practical contributions that the Tropics can make in response to climate change. These contributions can assist in solving a problem largely imposed on the region by the rest of the world.

Keywords The tropics • Geography • Climate change • Effects of temperature

This book is about the impacts of climate change on the Tropics. The Tropics is a somewhat unusual area of the Earth's surface, because unlike most similar groupings of nations such as Europe or Australasia, it is a region defined entirely by physical rather than political boundaries. The Tropics as a zone is defined by two lines of latitude, the Tropic of Cancer in the north and the Tropic of Capricorn in the south. These imaginary lines are the two circles around the Earth that mark the latitudes of 23.5 degrees north, where the sun is directly overhead at noon on June 21st (midsummer in the northern hemisphere) and 23.5 degrees south where the noon

R. Vale (✉) • B. Vale
School of Architecture and Design, Victoria University of Wellington, Wellington, New Zealand
e-mail: robert.vale@vuw.ac.nz

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sun is directly overhead on December 21st (midsummer in the southern hemisphere). The names of the two tropics are derived from the constellations in which the sun appeared at these times when the two lines were defined in the distant past (Jordan 2015).

Thanks to this physical definition the Tropics as a region comprises a much wider range of nations and cultures than most politically-derived groupings. The Tropics includes much of Central and South America, most of Africa, India, Pakistan and Bangladesh, Thailand, Cambodia, Vietnam and the southern tip of China, the whole of Indonesia and the Philippines and the top third of Australia. (Edelman et al. 2014; 7). It is a zone of great cultural differences and of great disparity of wealth and its occupants are numerous, the region is home to around 40% of the world population (Edelman et al. 2014; 15). What all these people share is not so much a common culture as a common climate.

This idea of a common climate for the Tropics is not entirely true although tropical regions are characterised by being hot, with the lowest monthly average temperature being 18 degrees C or higher. Nearly all areas in the Tropics fall into either the "tropical" or "dry" zones of the Köppen climate classifications (Chen and Chen 2013). However even in otherwise hot tropical areas there can be quite different local climates, for example potatoes are widely grown on the Dieng plateau in tropical Java, Indonesia, because it lies about 2000 metres above sea level and is consequently much cooler than the surrounding lower areas.

1 Limiting Climate Change by Limiting CO_2

The Tropics is already a region characterised by high temperatures, but with climate change, temperatures that are already high are likely to become even higher. The United Nations Environment Programme has stated the need to limit global average temperature rise to no more than 1.5 or at most 2 °C compared with the pre-industrial level to prevent serious social, economic and environmental problems by 2100 (UNEP 2010). According to the UK Meteorological Office, by the end of 2015 the global average temperature was already 1 degree Celsius above the pre-industrial figure (Met Office 2015). When measurements of carbon dioxide, the principal "greenhouse gas" causing this temperature increase, started to be made at the Mauna Loa observatory in Hawaii in March of 1958, the concentration of CO_2 in the atmosphere was around 315 parts per million (ppm) and it has risen every year since measurements began (US Dept. of Commerce et al. 2016). A thousand years ago, before the Industrial Revolution when carbon-based fossil fuels began to be consumed on a large scale, the level of CO_2 was around 280 ppm (Etheridge et al. 1996).

There is a clear link between the amount of CO_2 in the atmosphere and the average temperature, the more CO_2, the higher the temperature. Scientists and even politicians have been aware of this link for a long time. For example, a paper presented in 2005 refers to the European Council ruling back in 1996 that the increase in

global average temperature should not exceed 2 °C. The paper goes on to say that a rise of even 2 degrees cannot be regarded as "safe" and the author concludes that stabilizing CO_2 in the atmosphere at 400 ppm carries a reasonable likelihood of staying below the 2 degree temperature limit (Meinshausen 2005). This is getting quite urgent as NASA reported in 2013 that the level of CO_2 in the atmosphere had reached 400 ppm (NASA 2013).

2 Limits Defined by the Paris Climate Agreement

Climate change is a problem on a world scale but while the politicians of the European Council 20 years ago seem at least to have grasped the need to halt the rise in global temperature, not all politicians have been so farsighted. Nearly 20 years after the European Council ruling, the CoP21, United Nations Framework Convention on Climate Change (UNFCC), 21st session of the Conference of Parties was held in December 2015 in Paris, France. After lengthy deliberations, politicians from 196 countries successfully negotiated the Paris Climate Agreement. This had the global goal of holding temperature increase to below 2° C above pre-industrial levels, with parties agreeing to make efforts to keep it below 1.5° C (Climate Action 2015). Meinshausen pointed out back in 2005 that a delay of even 5 years in implementing a reduction in emissions would make it much harder to avoid a harmful rise in temperature.

The Paris Climate Agreement is expressed in terms of global temperature rise while concentration of CO_2 in the atmosphere is usually expressed in parts per million (ppm), or more correctly as parts per million by volume (ppmv) and the relationship between atmospheric concentration and possible temperature increase is not precise. The Intergovernmental Panel on Climate Change (IPCC 2007) refers to

> …the likelihood of exceeding an equilibrium temperature threshold of 2 °C above pre-industrial levels based on a range of published probability distributions for climate sensitivity. To render eventual exceedance of this exemplary threshold 'unlikely' (<33% chance), the CO_2-equivalent stabilisation level must be below 410 ppm for the majority of considered climate sensitivity uncertainty distributions (range between 350 and 470 ppm).

The IPCC stated some time ago

> ... to achieve a 450ppmv concentration target, average carbon emissions per capita globally need to drop from about 1 tonne today to about 0.3 tonnes in 2100... (Banuri and Weyant 2001, 89)

Even to limit future atmospheric CO_2 to 450ppmv, 50ppmv higher than at present, average global emissions need to fall by 70%. However it should be noted that James Hansen of NASA and co-researchers made the point in 2008 that a limit of 450ppmv is too high and that a target of 350ppmv is needed to avoid severe problems in the future. (Hansen et al. 2008). To meet this target would mean zero carbon emissions (Baer et al. 2009).

As the UK Met Office has stated, with an average temperature now 1 degree C higher than normal, humanity is already two thirds of the way towards the UN's lower limit and even with this apparently small increase already signs of a changing climate can be seen. As the US Environmental Protection Agency states " Extreme weather events are becoming more frequent and/or severe around the world. This is consistent with what we expect with a warming planet" (EPA 2016). It is not only the United Nations that has shown concern about climate change, the World Bank has described climate change as "the biggest market failure in human history" (World Bank 2009, 61).

3 Climate Change in the Tropics

It appears highly likely that the effects of climate change will be more severe in the tropics than in the cooler parts of the world. Examples of this concern have appeared in the literature over an extended period. For example in 2009 Kjellstrom et al. (2009) suggested that temperature rise as a result of climate change in countries that are already hot could result in people being unable to work when exposed to such temperatures, which would threaten agriculture, construction and other outdoor activities. Reacting to comments by Pope Francis at the time of the Paris Conference that the poor would suffer most from climate change, Martin, writing in the *MIT Technology Review*, supported this view, listing drought, flooding and disease as the principal climate-related threats to human life and agriculture in the Tropics. The Tropics are more at risk because, as Martin concluded, "normal temperature ranges in the tropics fall within a narrower range than those in more northern climes, and so any deviation is likely to have more significant effects" (Martin 2015). This is supported by the work of Mora et al. at the University of Hawaii, who found that "..." Unprecedented climates "[ie. where climate exceeds the bounds of historical variability] will occur earliest in the tropics" (Mora et al. 2013). Their study found that the first city to experience this unprecedented climate, which they predicted to happen by 2020, would be Manokwari, the capital of West Papua, Indonesia, and before 2030 Singapore, Jakarta, Kuala Lumpur and several other major cities in the Tropics would be in the same situation (Moralab n.d.). It will not be long before many tropical cities will be experiencing climates unlike anything they have experienced before.

According to UN Habitat the built environment of cities is a source of much of what drives climate change; " Cities are major contributors to climate change: although they cover less than 2 % of the earth's surface, cities consume 78% of the world's energy and produce more than 60 of all carbon dioxide and significant amounts of other greenhouse gas emissions, mainly through energy generation, vehicles, industry, and biomass use." (UN Habitat 2012) The same source shows that the built environment is not only a contributor to climate disruption but also one of its victims; "cities and towns are heavily vulnerable to climate change. Hundreds of millions of people in urban areas across the world will be affected by rising sea

levels, increased precipitation, inland floods, more frequent and stronger cyclones and storms, and periods of more extreme heat and cold." (UN Habitat 2012).

In spite of the fact that the Tropics is home to 40 % of the global population, as a region it produces only 15 % of the world's greenhouse gas emissions (Edelman et al. 2014; 15). It seems unfair that the region of the earth which will likely suffer the most as a result of climate change due to emissions that it has not caused is still required to play its part in reducing emissions. To show the contribution that the Tropics can make in solving a problem that is largely not of its own making, this book provides a wide range of examples that have been proposed by researchers.

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Part I
The Sustainability of the Built Environment

Chapter 2
Climate Change and the Sustainability of the Built Environment in the Humid Tropic of Indonesia

Tri Harso Karyono

Abstract As a developing country, Indonesia needs to develop its facilities and infrastructure to improve its people's wellbeing. As a consequence of the development, much of its energy sources, particularly its fossil fuels, have to be consumed, emitting a huge amount of carbon dioxide, accelerating global warming and climate change. In many cases, development would increase a country's carbon emissions and its ecological footprint (EF), which could threaten the sustainability of the whole earth. Indonesia is no exception; the development of this nation would emit much more carbon dioxide as around 95 % of this country's energy demand is supplied currently by fossil fuels. Considering the fact that Indonesia has a huge potential of renewable energy sources, substituting the fossil fuels by renewable sources would help this country to develop without emitting so much carbon dioxide, thus retarding the effects of climate change. Along with the diversification from fossil fuels to renewable energy, changing the human attitudes so as to behave wisely to use less energy would help this country keep its EF low, thus sustaining its development without adding to global warming and climate change.

Keywords Carbon emission • Climate change • Development • Fossil fuels • Renewable energy

1 Introduction

Many disasters have occurred in many places all over the world within the last decades. This gives a strong hint that something has changed on this earth. The impact of global warming is clear and the global climate has already changed. The changes of global climate give many consequences to the earth and thus for people's lives. Heavy rains create big floods which now occur not at a common time and not in common places. Forests burn not in the dry season as happened before, fire occurs more frequently at any time even during the rainy season. Anything can occur

T.H. Karyono (✉)
School of Architecture, Tanri Abeng University, Jakarta, Indonesia
e-mail: t_karyono@yahoo.com

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anywhere at any time. Weather forecasters may become unable to forecast as unexpected factors may change everything unpredictably.

Looking at the built environment aspect, the cause of climate change is obvious. In addition to the increase of human population, so many new things and activities have been created since the industrial revolution. The addition of human population and the new activities created by human beings require new infrastructures, facilities and buildings to be built to accommodate them. Most of these things are designed or proposed by architects. In a simple view, the work of architects is to craft the earth's surfaces. Unlike the ordinary craftsmen, architects have to craft them with huge responsibilities laid on their shoulders. Architects have to create these kinds of products such as buildings, bridges, towns, etc., to be aesthetic, but also to be functionally correct, and at the same time, these things have to minimize the use of earth's resources, to consume less energy and emit less carbon. Strictly speaking, architects have to consider that crafting the skin's earth must be ecologically friendly, conserving earth's resources, minimizing the use of energy, minimizing carbon emissions, producing less waste, and last but not least, not sacrificing the quality of human life to have a safe, healthy and comfortable living environment.

In many cases, architects fail to do this. Many of them have built buildings, towns and other man-made environments which have degraded the environment in many ways. They unconsciously destroy the natural environments, whether seaside, swamps, lakes, rivers or forests, by converting them into buildings, housing, offices, commercial facilities, and even towns. Figure 2.1 shows a reclamation area on the

Fig. 2.1 A reclamation area of Pantai Indah Kapuk, Jakarta: Architects and planners destroy a natural coastal environment, creating urban heat islands and raising the ambient temperature of the city

seasides of North Jakarta. The developer and the local authority do not consider this development may have degraded the natural environment and the ecological system. Many green areas, with an abundance of trees and wildlife, have been removed, replaced with concrete, asphalt and other hard surface materials. This has created changes in the micro climate in many parts of the earth's surface. Ambient temperatures rise, clean water runs out and the wildlife disappears. The changes of the earth's skin environment from natural to man-made have created huge environmental problems in many ways. The urban heat island phenomenon, in which the built up areas are becoming much warmer than their surrounding environments, has taken place everywhere.

On the other hand, the increased number of the human population and the rapid increase in use of modern technology has increased the energy demand. Most of all current human activities require energy, which is quite unfortunate given that the energy being used today is mostly derived from fossil fuels, emitting a huge amount of carbon dioxide in the generating process. The huge emission of CO_2 is scientifically proven to be the cause of global warming and climate change. The latest data of The World Bank in 2013 showed that around 81.2 % of the world's energy use is generated from fossil fuel (World Bank 2016), the rest from alternative, renewable and nuclear energy.

All the combined problems have to be learned and to be solved. How could we build buildings and other man-made environments, such as a town, that can be safe, healthy and comfortable, without resulting in the degradation of the environment, emitting less carbon dioxide and preventing the rise of keeping the earth's temperature?

The recent development of Indonesia, as in other developing countries, has concerned environmentalists that the development has degraded the country's natural environments. Development has produced many new buildings, settlements and towns. However, unlike in the past, in which our ancestors had been successfully handling the environment wisely by limiting the use of natural resources, the new development has encouraged people to use more energy and natural resources. The trained Indonesian architects and urban planners are unlikely to do as wisely as our ancestors did. Today, many buildings and towns are designed without considering the local climate and culture. Furthermore, the lack of reference to informal wisdom and the poor formal building codes have created environmental problems in many ways, such as floods, traffic congestion and so on. The worst part of the development of Indonesia is that it has encouraged people to use more energy, emitting more CO_2, creating global warming and climate change. Some problems caused by climate change, such as floods, have afflicted many large Indonesian cities, such as Jakarta. In order to mitigate climate change, some strategies are proposed below.

2 Indonesia as a Tropical Developing Country

Indonesia lies between the Pacific and Indian Oceans, it stretches along the equator and scattered over both sides for a distance of 6400 km, and lies between 11° south latitude and 6° north latitude, and 95° and 141° east longitudes (Wikipedia, Indonesia 2016a). The largest archipelago in the world, Indonesia is formed of 17,508 islands, only about 6000 of which are inhabited (CIA 2016). Java, the fifth largest island in Indonesia after Kalimantan, Papua, Sumatera and Sulawesi, is the most densely populated island in Indonesia. More than 135 million out of the country's 240 million population live on this island. Java is recorded as the world's most populous island (Wikipedia, Java 2016c). Figure 2.2 shows the Mount Kie Matubu in Tidore Island, North Maluku, Indonesia. Hundreds of mountains and volcanoes in Indonesia are not only shaping the beauty of its landscapes, but also fertilize the soil, creating a perfect closed chain of the ecological system.

With around 127 active volcanoes (Wikipedia, list of volcanoes 2016f), Indonesia is the country with the largest number of active volcanoes in the world. With so many volcanic eruptions over a long time, the volcanoes' ashes help to fertilize the country's soils. People can easily grow vegetables, plants and trees anywhere in this country without fertilizer. There is a big potential for the Indonesians to live autonomously without depending on the global food industry.

With 98 million hectares of rainforest (Orangutan Foundation 2016), 326 million hectares of sea and 9.3 million hectares of freshwater (Wikipedia, Geography 2016e), this country could absorb huge amounts of CO_2 annually. The rainforest could take up 5 tonnes of CO_2 per hectare per year (Bao and Phan 2011), which means all the Indonesian forest could help to reduce CO_2 annually by 490 million tonnes.

Fig. 2.2 Mount Kie Matubu in Tidore Island, at the back of the small island of Maitara, North Maluku, Indonesia

The forests of Indonesia represent 10 % of the world's remaining tropical forests. Indonesia's forests are the second largest in the world after Brazil (Orangutan Foundation 2016). The diversity of Indonesia's flora and fauna and the fertility of its soil create a perfect closed chain of the ecological system. Figure 2.3 shows Maribaya forest, West Java, Indonesia. When the Indonesian natural environment, forests and the sea are conserved, they will curb a quite large proportion of world carbon emissions.

However, the country's potentials have been neglected somehow. The country's recent economic development has increased people's ability to get more things. Along with this, the modern economy has driven people to buy things that they do not actually need. Modern food technology has offered fancy products that attract people to consume them. Within a few decades, there has been a changing of Indonesians behaviour towards life, from practicing a simple and traditional way of life to a modern life. The changes of attitude towards life change the use of technology to support that life. Modern technology is an avoidable thing to be used as it helps people to have everything faster and easier in some way.

Modernity enhances people's ability to increase their living standards, increasing the quantity of earth's resources to be consumed. Forests are cut down to allow the development of massive plantations, such as palm oil, and also for new industry.

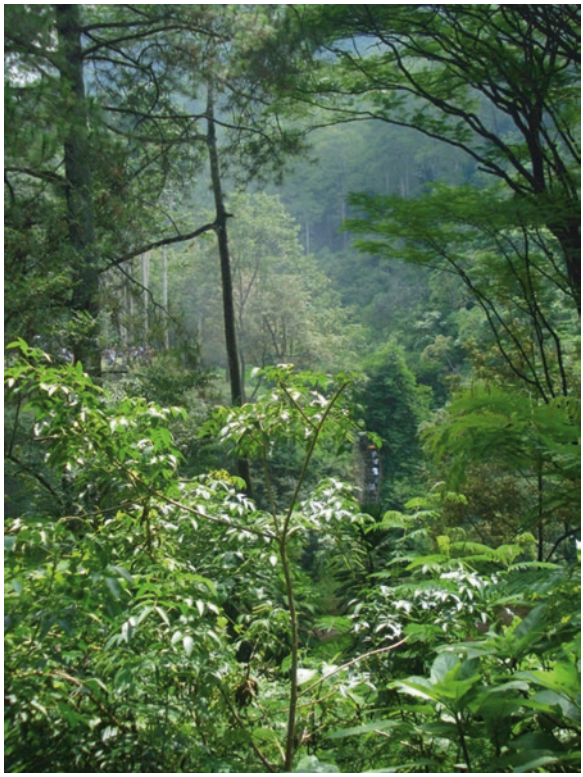

Fig. 2.3 Maribaya forest, West Java, Indonesia. The tropical rain forest is a perfect closed chain of the ecological system

On the other hand, huge areas of paddy-rice fields have been replaced by houses, buildings and even new towns. Indonesia has started to be a food importing country as the food production has declined while its demand has increased.

3 Problems of Improving the Wellbeing in the Developing Countries

Like most of the developing countries, Indonesia is no exception. This country needs to improve its people's wellbeing to be more prosperous. To achieve this, this country needs to build many more infrastructures, buildings and other facilities. More roads, railways, bridges, are needed to connect towns and places. More houses need to be built to accommodate people and population growth. More schools are needed to be built, as well as hospitals, public libraries, and other public facilities to facilitate the society's needs. Figure 2.4 shows Muara Angke settlement with a background of exclusive apartments. The gap between the poor and the rich is quite wide, while the poor want to have an equal opportunity.

On the other hand, the prosperity of the nation is likely to be associated with a country's gross domestic product (GDP) and human development index (HDI). Prosperous countries tend to have GDP and HDI higher than those of the poor countries. The developed industrialized countries tend to have GDP and HDI higher than the developing countries. Improving a nation's wellbeing for a developing country such as Indonesia, means that many things have to be built and developed, which in turn requires a lot of energy and natural resources. Increasing the use of energy would increase the country's carbon dioxide (CO_2) emissions since most of the

Fig. 2.4 Muara Angke settlement with a background of exclusive apartments, Jakarta

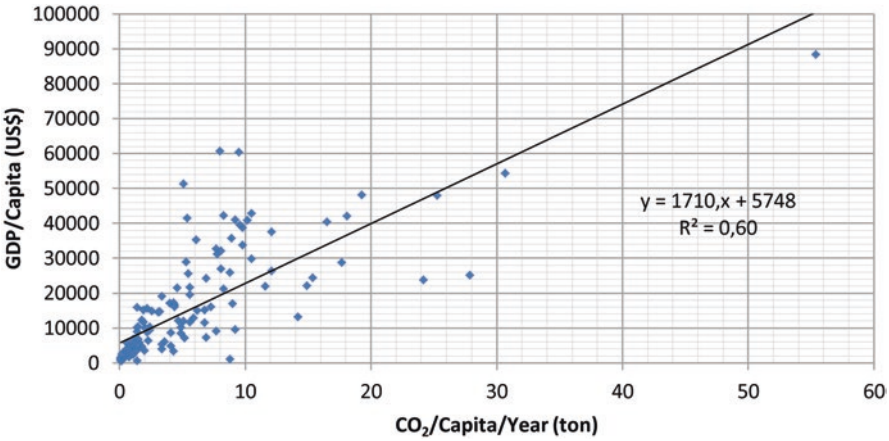

Fig. 2.5 Linear regressions of GDP on CO_2 (Revision of Karyono's chart 2013)

energy in Indonesia is derived from fossil fuels. At the same time, increasing the use of natural resources would increase the country's ecological footprint (EF).

There is clear evidence that improving a nation's well-being, in terms of the gross domestic product (GDP) and human development index (HDI), would increase the nation CO_2 emissions and EF. Examining 143 countries with the available data on their GDP (Wikipedia, GDP 2013, Countries of the World 2009), HDI (Wikipedia, HDI 2016b), CO_2 (Wikipedia, CO_2 2016d) and (EF) (Global Footprint 2010), it was found that the above indexes are correlated with each other. The calculation is based on the data of countries' GDP, HDI, CO_2 and EF in 2007. This date has been used since the world's EF is most recently reported for this year. To make all the data comparable, the analysis must be using the same time, that is 2007. Figure 2.5 shows a graph of the correlation between GDP (US$) and$CO_2$ emissions (tonnes/capita) taken from 143 countries with the available data. The regression equation is expressed as:

$$GDP = 1710\ CO_2 + 5748 \tag{2.1}$$

With the coefficient of determination (R^2) of the line being 0.6, it shows that there is a strong correlation between GDP and CO_2 emissions. Although each country has its own specific correlation between its GDP and CO_2 emissions as it is based on the energy sources being used by the country, an increase of a nation's GDP is likely to increase the country's CO_2 emissions. France is an exception. This country emits a relatively low amount of CO_2 to increase its GDP. Around 78 % of France's electricity is generated by nuclear power, emitting low CO_2 emissions. Having a GDP of US$ 35,247 per capita, France emits only 6.1 tonnes CO_2 per capita, which is about 0.2 kg CO_2 for each single dollar to raise its GDP. This is the lowest CO_2 production per unit GDP among the world's major industrial countries (Wikipedia, CO_2 2016d). In order to keep a low CO_2 emission value a country must minimise the

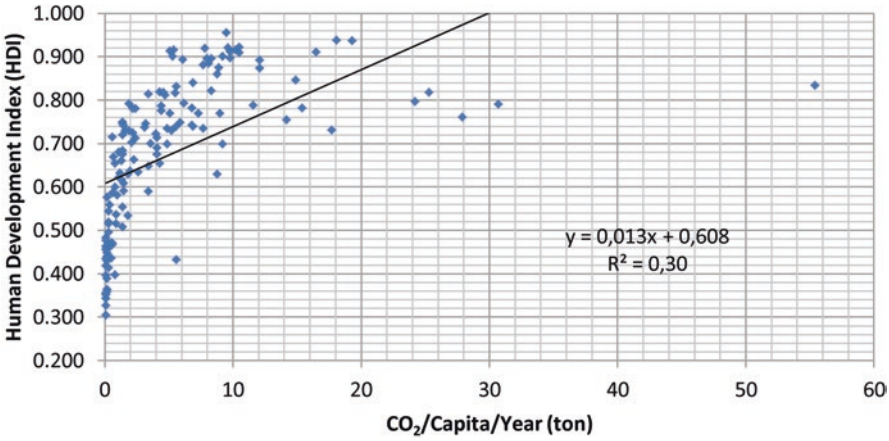

Fig. 2.6 Linear regressions of HDI on CO_2 (Revision of Karyono's chart 2013)

use of fossil fuels. Diversifying from fossil fuels to nuclear power as France does may not be recommended for Indonesia as this country has a huge potential of renewable energy sources, which can be developed to substitute its fossil fuel consumption.

A Pakistani economist, Mahbub ul Haq, developed a Human Development Index (HDI) in 1990, which is used by the United Nations to partly express the wellbeing of any country in the world. To see the relationship between a country's HDI and its CO_2 emissions, a regression line of HDI on CO_2 emissions is constructed. Figure 2.6 shows a linear regression line of HDI on CO_2. The regression equation is expressed as:

$$HDI = 0.013\ CO_2 + 0.597 \tag{2.2}$$

The coefficient of determination of the regression (R^2) is 0.3, or 0.55 in terms of the coefficient of correlation. The correlation of HDI and CO_2 is less strong than that between GDP and CO_2. The higher the HDI of a nation the more the nation would tend to emit CO_2.

William Rees and Mathis Wackernagel of the University of British Columbia, Canada, introduced the terms of Ecological Footprint (EF) in 1992 to measure humanity's earth's resources consumption. EF, which is measured in global hectares (gha), is a calculation of human demand on the earth's resources, standardized by land and sea areas that can regenerate resources being consumed by the population and mitigate associated waste (Global Footprint 2010). The higher the EF, the more the individual or nation consumes the earth's resources and produces more waste. Using EF as a parameter to measure national demands for the earth's resources, GDP and HDI seem closely related to the nations' EF levels. A nation with high GDP and HDI tends to have a high EF, which means that GDP and HDI tend to have a positive correlation with the consumption of earth's resources.

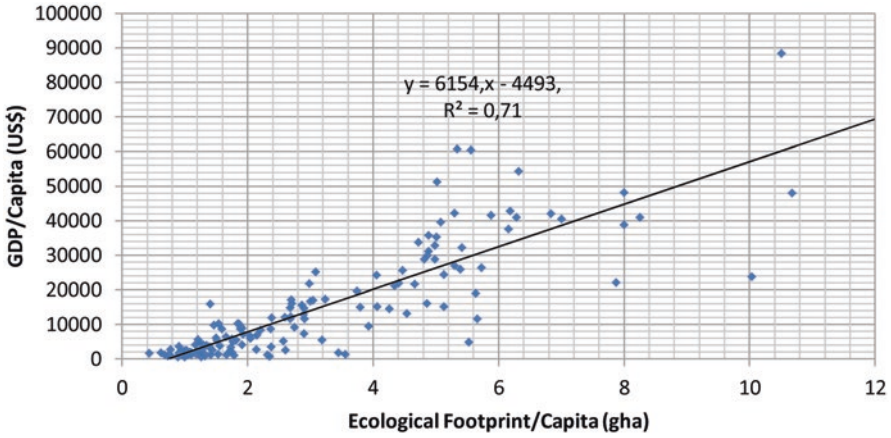

Fig. 2.7 Linear regression of GDP on EF (Revision of Karyono's chart, 2013)

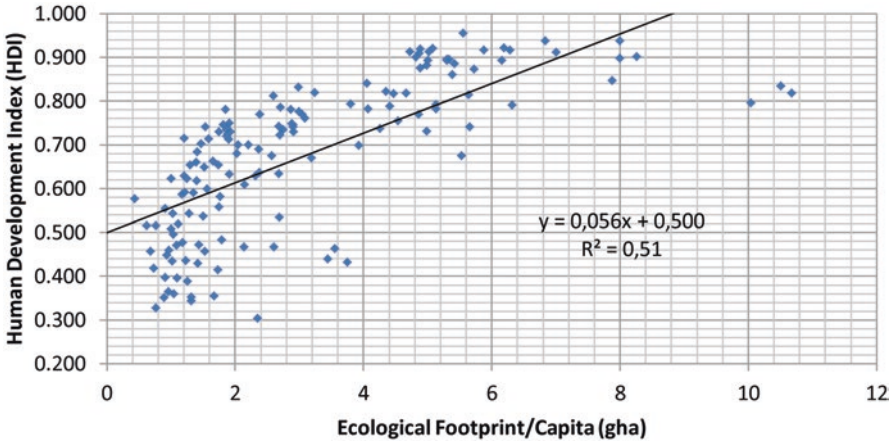

Fig. 2.8 Linear regression of HDI on EF (Revision of Karyono's chart, 2013)

In terms of GDP, Fig. 2.7 shows a linear regression line of GDP on EF. The regression equation is expressed as:

$$GDP = 6168EF - 4602 \tag{2.3}$$

Having 0.7 as a coefficient of determination (R^2) or 0.85 as a coefficient of correlation (r), the correlation between GDP and EF is quite strong. The higher the GDP of a nation, the higher the demand for earth's resources, requiring more land to be used. The correlation between GDP and EF is even stronger than the correlation between GDP and CO_2 emissions.

In terms of HDI, Fig. 2.8 shows a regression line of HDI on EF. The regression equation is expressed as:

$$HDI = 0.058EF + 0.487 \tag{2.4}$$

Having a coefficient of determination of 0.5 or coefficient of correlation of 0.7, the higher the HDI the higher the nation would consume the earth's resources. To improve a nation's well-being, there would be an increase in consumption of earth's resources, requiring more area of land to be used and increasing EF levels.

Generating electricity with nuclear power and renewable energy, such as wind turbines, solar PV or hydro would help the country in reducing its CO_2 emissions. However, it might not help too much with the EF reduction, since any energy generator would occupy a certain amount of land. The more energy is generated the more area of land is needed, increasing EF levels. In order to reduce the EF, a country must reduce its resource consumption, including food and minerals as well as energy. Reducing a nation's energy consumption, instead of diversifying to renewable and nuclear energy, is perhaps the best way to reduce a country's EF.

4 Climate, Development and Energy Consumption

To mitigate climate change, the world carbon emissions must be reduced. In the current situation, reducing carbon emissions would reduce the nations' GDP and HDI, degrading people's living standards and their wellbeing. The question is how to find a way of cutting a country's carbon emissions without degrading living standards? Improving the quality of the built environment is to create a healthier and comfortable environment. The improvement of our built environment could be done, even without the escalation of CO_2 emissions.

Climate affects people's life, behavior and in the end, their energy consumption. In a cool climate, people have to use more energy (electricity) for heating spaces, hot water, etc.,as without it, life would be miserable. In the winter, people have to encounter the low outdoor temperatures, making it very hard to live and work in the outdoor environment. Buildings are an important means to protect people from the unwanted cold weather. A building is not only a matter of a spatial form to accommodate people with their activities, but, a building is also a device which is used to modify an extreme outdoor environment to be moderate and comfortable enough to accommodate people keeping their activities at a normal metabolic rate.

To create a comfortable building, while the outdoor temperature is extremely low; heating up the indoor spaces is required. In this case, the use of energy for space heating is a must, making people highly dependent on the energy. This kind of circumstance, however, does not apply to a tropical climate, such as Indonesia. There is no need for heating up the rooms, though there might be an opposite action which must be taken, in which, cooling is necessary in some particular conditions.

Almost all of the regions of Indonesia tend to be warm, except those in the mountainous or highland areas where the air temperature is relatively low. Only a small number of Indonesians live in these cool areas. Thick clothes and space heating may be required by people in these areas.

On average, the prevailing moderate climate in the tropics, which is neither too cool nor too hot, has actually provided a greater chance for Indonesians to consume

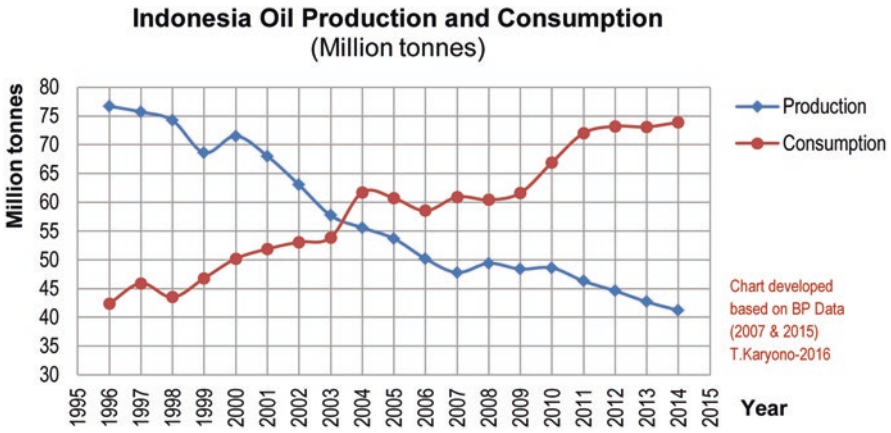

Fig. 2.9 Indonesia oil consumption surpassed its production in 2004

less energy than people who live in the temperate climate. To provide comfortable buildings, Indonesians need less energy than people who live in a country with more extreme climate condition, such as in the desert and near the poles. Having a prevailing outdoor temperature of between 18 to 32°C, which is relatively close to the skin temperature, many Indonesians living in the towns are relatively comfortable without heating or cooling. A number of homeless people can still sleep well in the open air on the roadsides with a minimum use of clothes. This would be certainly impossible for those living in the cold climate. A tropical building may need only a roof, no walls, to protect the occupants from rain and strong solar radiation. Since the dependency on energy is small, people in Indonesia have a better chance to sustain their built environment since they could burn less fossil fuel to provide a comfortable house and building. However, the facts have shown differently.

Along with the development of the nation, Indonesia's energy consumption has increased considerably since the New Order government took power in the middle 1960s. Along with the country's massive development since 1970, the country's oil consumption has risen steadily, while its production has continuously declined. In 2004, the oil consumption surpassed the production. The gap between them is getting bigger and bigger since Indonesia very much depends on oil (BP 2007, 2015). On the other hand, it is still fortunate for Indonesia that until now its natural gas and coal productions are still over the consumption. The new data show that in 2014 the country's natural gas production was 66.1 million tonnes oil equivalent (toe) and the consumption was 34.5 million toe, while the coal production was 281 million toe and the consumption was 60.8 million toe (BP 2015). Figure 2.9 shows Indonesia oil consumption surpassed its production in 2004.

Apart from producing a proportion of fossil fuels (oil, gas and coal), this country has abundant of renewable energy sources, such as geothermal, solar, hydro and biomass. However, this huge potential of renewable energy sources is still far from being utilised. The country's electricity still largely depends on fossil fuel. Nearly