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Article

An Integrated Approach to Analyze the Progress of Developing Economies in Asia toward the Sustainable Development Goals

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Abstract: This study endeavored to analyze the progress made to meet the Sustainable Development Goals in terms of resource use, sustainable production and consumption, and the triple planetary crisis (i.e., climate change, biodiversity loss, and pollutant emissions) at the national and regional levels in Asia. The study highlighted that the progress toward sustainable consumption and production is still not sufficient to meet the ambitious national targets. An urgent need for a comprehensive approach to address climate change, biodiversity loss, pollutant emissions, and resource use has been ascertained. China's greenhouse gas emissions have surged tremendously. India is also endeavoring to decouple emissions from growth via renewable energy. Vulnerable Pakistan seeks emission reduction and financial aid. Indonesia, Thailand, and Vietnam outline emission reduction strategies. Land use change emerges as a key biodiversity loss driver, stressing the need for sustainable land policies and conservation. Material consumption highlights the call for production optimization, circular economies, and innovative technology. Energy's role in development requires decoupling from growth through efficiency, renewables, and eco-friendly paths. Freshwater needs careful management for sustainability, and international collaboration and policy reform are urged for global water use efficiency. Decoupling trends between growth, resource use, and environmental impact show a complex pattern, with the feasibility of absolute decoupling limited by growth interdependence.

Keywords: sustainable development goals (SDGs); Asia; resource use; sustainable consumption and production; triple planetary crisis

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1. Introduction

This century is widely recognized as the Asian era, with Asia emerging as a central global hub for both production and consumption [1,2]. The consumption trends within Asia are swiftly shifting toward greater material affluence, driven by the combined forces of escalating urbanization and a rapid transition from lower- to middle-income populations [3,4]. Traditionally, this region has been characterized by saving-oriented behavior rather than lavish spending. However, if the increasing population in Asia were to adopt consumption patterns similar to those of the average American or European population, it could strain the Earth's resources to an unsustainable extent, causing irreversible damage [1]. Moreover, the three distinct and interconnected environmental challenges, i.e., climate change, biodiversity loss, and pollutant emissions, also referred to as the triple planetary crisis, pose significant threats to human well-being, socio-economic systems, and the long-term sustainability of the planet, necessitating urgent and coordinated global action [5,6]. Climate change and the associated environmental repercussions are estimated to cost a cumulative damage of around USD 8 trillion by 2050, reducing the global gross domestic product (GDP) by 3% and disproportionately affecting the poor regions [7]. Asia is also endeavoring to tackle these three distinct environmental crises, which pose unique challenges to the region [8]. On the other hand, the region's economic growth has shown a positive trajectory, with the GDP growth reaching approximately 5.8% in 2021 [9,10]. This emphasizes the importance for Asian member states, particularly developing nations, to embrace sustainable consumption and production (SCP) patterns.

The United Nations endorsed 17 Global Goals in 2015, also known as the Sustainable Development Goals (SDGs), as a worldwide call for action to eradicate poverty, protect the earth, and to ensure that all people enjoy peaceful and prosperous life by 2030 [11]. In the diverse landscape of Asia, significant variations exist in the progress toward different SDGs and within various sub-regions. Overall, the region is falling short of achieving most of the SDG targets. Certain goals, such as no poverty (Goal 1), zero hunger (Goal 2), quality education (Goal 4), reduced inequalities (Goal 10), and partnership for the goals (Goal 17), show some promising advancement; however, the pace is still insufficient to meet the desired objectives [12].

One of the central challenges is the lack of coherent and effective policies with measurable impacts that can foster an environment conducive to sustainable practices, supported by legal and economic incentives [13,14]. Reliable information and data are also essential when dealing with the aspects such as resource consumption and resource efficiency [15,16]. Moreover, financial and geopolitical limitations may also influence the regional landscape, hindering businesses from adopting more efficient and innovative approaches, such as environmental, social, and governance (ESG) investing, and circular economy [17–19]. Consumer awareness also remains a significant obstacle to the adoption of sustainable products. Addressing the dearth of reliable information related to the aforementioned challenges is pivotal to overcoming them.

On the other hand, the region's economic growth has led to intensive resource utilization, negatively impacting responsible consumption and production (SDG 12). Greenhouse gas emission reduction targets aligned with the SDGs are proving difficult for all sub-regions of Asia to achieve. The region's resource efficiency performance lags behind rest of the world. Resource efficiency entails utilizing Earth's finite resources sustainably while minimizing the environmental impacts, enabling more efficient production with less input [20]. Notably, Asia's consumption of national resources per unit of GDP exceeds the global average by 60%, and CO_2 emissions per unit of value added exceed the global average by 20% [21]. Thus, the region is significantly deviating from a fair global share of resource consumption.

Consequently, Asia grapples with escalating environmental challenges, encompassing emission and waste issues, efforts to decouple economic growth from unsustainable resource use, inefficient manufacturing processes, and environmental deterioration [22]. Nonetheless, progress is non-linear, necessitating accelerated strides toward a resource-efficient economy to address regional predicaments. This entails potential for improvement through the adoption of best practices, such as implementing lean manufacturing principles, optimizing energy, material, and water use, embracing circular economy strategies, and leveraging digital technologies for process optimization, particularly for countries and businesses lagging in progress.

Currently, Asia contends with the impacts of climate change, increasing regional disparities in environmental performance and inconsistent policies. This study aims to understand the interlinkages between regional challenges, primarily related to the sustainable consumption and production, resource efficiency, as well as the triple planetary crisis issues. The objective is to comprehend how SCP connects with regional issues and countries' predicaments, elucidating the current status and impacts related to consumption and production patterns. The crucial factors influencing changes in regional issues and difficulties faced by the countries need to be identified to explore possibilities for improvements. Furthermore, conducting a country-based study focusing on several aspects, such as sustainable consumption and production, resource efficiency, and the triple planetary crisis, could serve as a rational model for addressing regional challenges. The holistic approach adopted in this study aims to facilitate the practical implementation of SCP actions, mitigating regional challenges and contributing to sustainable betterment.

2. Methodology

In this study, we employed a methodology to assess the progress of SDG development, focusing on multiple aspects, such as the triple planetary crisis, resource efficiency, and sustainable consumption and production. The process began by identifying the relevant indicators for both the triple planetary crisis and resource usage. Subsequently, a connection was established between the SDGs and the chosen indicators. Lastly, a comprehensive Driver–Pressure–State–Impact–Response (DPSIR) analysis was conducted to systematically assess policy impacts and facilitate informed decision-making that addresses both developmental and environmental complexities. The developed framework is characterized by its adaptability and ease of customization, allowing it to effectively incorporate and facilitate various types of analyses based on specific and distinct requirements. This adaptability ensures that the framework can be efficiently tailored to accommodate a wide range of analytical approaches depending upon the unique demands of each study or investigation. A thematic depiction of the adopted approach is provided in Figure 1 and the particulars of each step are elaborated below.

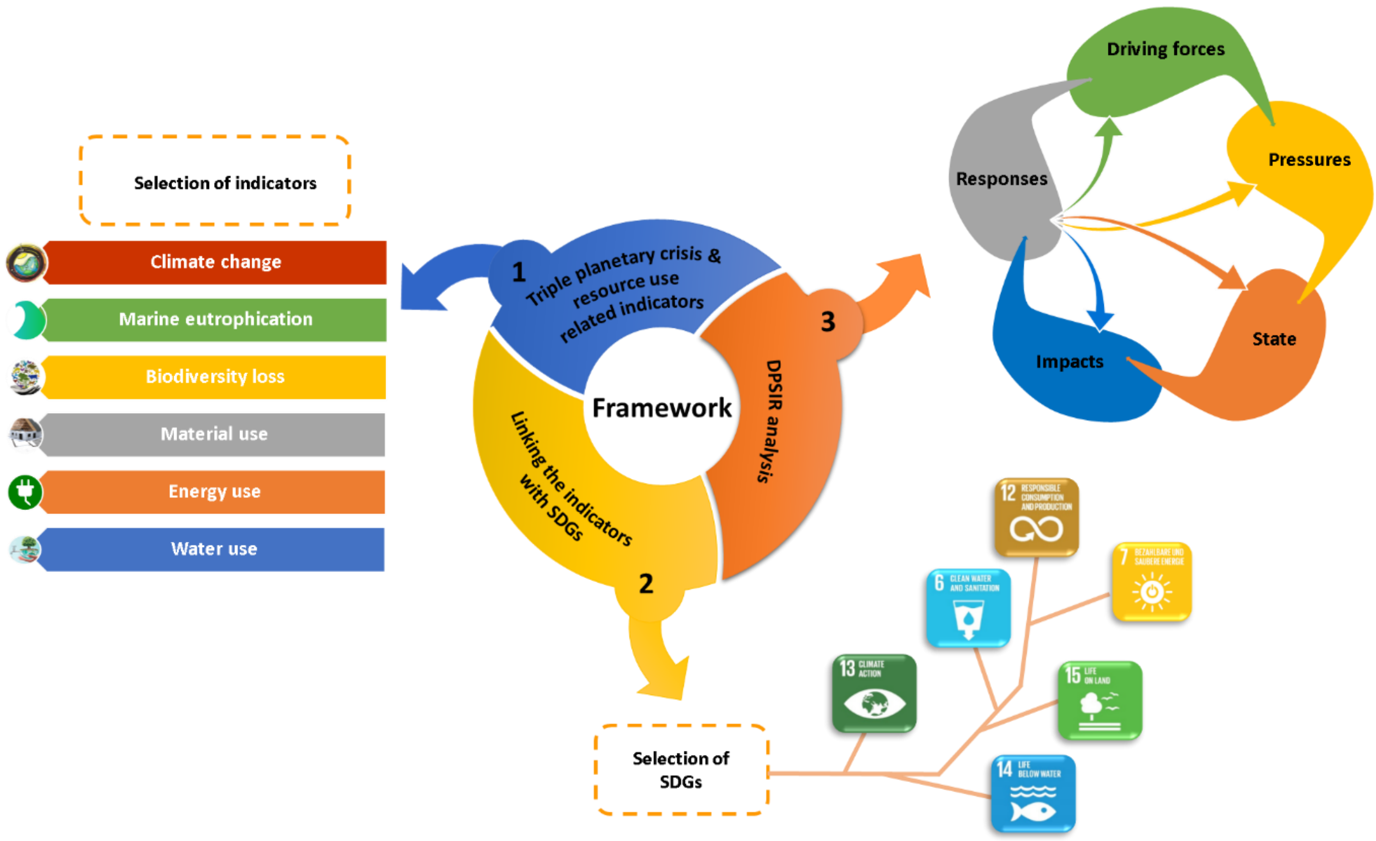

Figure 1. A thematic depiction of the methodology adopted in this study.

2.1. Selection of Triple Planetary Crisis and Resource Use Indicators

The indicators were chosen to reflect the triple planetary crisis, resource use, and resource efficiency aspects, with the intention of comprehending the performance of selected countries toward the SDGs considering developmental and environmental challenges, thereby identifying trade-offs and potential opportunities. The indicators for the triple planetary crisis encompass climate change, pollutant emissions, and biodiversity loss [7].

Furthermore, the crucial resource use indicators encompass materials, energy, and water consumption. These indicators find widespread application in analyses of this nature, be it at the product, national, or regional level. For instance, Ghani et al. [23], Mahmood et al. [24], and Gheewala et al. [1,2] have utilized such indicators in their respective studies. More detailed information about each indicator is presented below.

A wide range of indicators were selected focusing on multiple aspects, including the triple planetary crisis (i.e., climate change, biodiversity loss, and pollutant emissions), resource use (consumption and production perspective), and resource efficiency (i.e., in terms of economy and a per capita basis). The selected indicators include: (1) climate change, (2) pollutant emissions in terms of marine eutrophication, (3) biodiversity loss, (4) material use, (5) energy use, and (6) water use. The data for each indicator were retrieved from the SCP Hotspots Analysis Tool (SCP-HAT) database, focusing on six countries: China, India, Indonesia, Pakistan, Thailand, and Vietnam [25]. These countries were chosen due to the intensive consumption of natural resources [1]. The data were available for the past three decades, from 1990 to 2018. In general, there are two analytical perspectives available in the SCP-HAT tool—domestic production ("territorial approach") or consumption footprint ("footprint approach")—to analyze hotspots of (un)sustainable consumption and production. Under the domestic production perspective, environmental pressures and impacts are assigned to the specific country where they physically take place. In other words, if a country produces goods or services, it bears responsibility for the environmental consequences that occur within its own borders during the production process. In contrast, the consumption footprint perspective attributes environmental pressures and impacts to the country where the final consumption of goods and services occurs. This means that if a country consumes a product or service, it takes responsibility for the environmental effects that occurred throughout the entire supply chain of that product. This includes not only the environmental impact within its own borders but also the impacts generated during production and transportation from other countries. In this article, both perspectives are considered to analyze the situation on production and consumption. Further details related to each indicator are provided below.

2.1.1. Climate Change

The environmental impacts related to climate change were measured in terms of the global warming potential of greenhouse gas (GHG) emissions by each country. The assessment was performed by focusing on three indicators: total GHG emissions, GHG emissions per capita, and GHG emissions per GDP, considering the production and consumption perspectives. The GHG dataset provided in the SCP-HAT is based on the Emissions Database for Global Atmospheric Research (EDGAR) v.6.0 [26], which combines several published datasets to create a comprehensive set of greenhouse gas emissions pathways for every country and the main greenhouse gases (CO_2, CH_4, and N_2O). There are two impact categories available in the SCP-HAT to measure climate change: (1) short-term climate change and (2) long-term climate change, measured in terms of global warming potential (GWP100) and global temperature change potential (GTP100) at a 100-year horizon, respectively. However, in the present analysis, only the short-term category was considered as GWP100 has widespread application in climate science and policy. It is useful for assessing the short-term impact of GHG emissions and for comparing and setting emissions reduction targets. Moreover, effectively addressing challenges related to climate change necessitates an approach that not only focuses on greenhouse gas emissions to be curtailed to mitigate society's impact on climate change, but this must also be achieved while fostering economic development, as measured by the GDP. In addition to focusing on domestic GHG emissions, attention must be directed toward the cumulative sum of GHG emissions generated along the supply chains of goods and services consumed within a country. This cumulative impact is commonly referred as the 'carbon footprint'. To gauge a country's progress in managing GHG emissions, the metric 'carbon productivity', which involves dividing GDP by GHG emissions, proves to be another valuable indicator. By analyzing the development of GDP alongside the carbon footprint, it becomes possible to ascertain whether a nation can successfully decouple its economic growth from the growth in GHG emissions.

2.1.2. Biodiversity Loss

The potential species loss from land use change is selected to assess the impact of land use on biodiversity (one of the triple planetary crises) for the concerned countries. Land use data provided in SCP-HAT focus on three main categories: agriculture, forestry, and built-up land. Agricultural and forestry land use is detailed in the FAOSTAT Land Use domain, which includes arable land, permanent crops, and pastures. The FAOSTAT Land Use domain also encompasses information on the forest area, which, when merged with data from the FAO Global Forest Resource Assessments, allows for the determination of extensive and intensive forest use areas. The characterization factors applied are country-level average factors used to assess global species loss due to land occupation. In the present analysis, the assessment was performed using three indicators: potential species loss from land use, potential species loss from land use per capita, and potential species loss from land use per GDP, from the production and consumption perspectives. The potential species loss from land use (milli-PDF*year or 10^{-3}-PDF*year) indicator measures the estimated number of species that could be lost due to changes in land use, represented in milli-PDF (potential disappearance fraction) per year. It quantifies the potential negative impact of human activities, such as deforestation or urbanization, on the biodiversity of an area. The potential species loss from land use per capita (pico-PDF*year/capita or 10^{-12}-PDF*year/capita) indicator assesses the potential species loss from land use on a per capita basis, represented in pico-PDF per year per capita. It considers the potential biodiversity loss relative to the population size of a country, providing insight into the ecological impact caused per capita by accounting for both potential species loss and population size. The indicator helps answer questions such as: How much potential biodiversity loss is each person responsible for based on their country's land use practices? Do larger countries with higher populations potentially have a more significant ecological impact, and vice versa? The potential species loss from land use (USD/femto-PDF*year or USD/10^{-15}-PDF*year) indicator evaluates the potential species loss from land use in economic terms, represented in USD per femto-PDF per year. It quantifies the potential economic cost associated with the decline in biodiversity resulting from land use changes.

2.1.3. Pollutant Emissions

The pollutant emissions are measured in terms of marine eutrophication. The selection of marine eutrophication as the proxy for pollutant emissions stems from several considerations. Firstly, marine eutrophication is a critical environmental issue caused by excessive nutrient inputs, primarily from human activities such as agriculture and wastewater discharge. This process leads to harmful algal blooms, oxygen depletion, and ecosystem degradation, making it a focal point for environmental concerns [27]. Additionally, marine ecosystems cover a significant portion of the Earth's surface and play a crucial role in global biogeochemical cycles and biodiversity [28,29]. In the SCP-HAT database, leached nitrogen information is derived from the FAO data [30], which include information on nitrogen use and nitrogen leaching. The indicator reflects the severity of marine eutrophication potential and is expressed in terms of nitrogen-equivalents. By choosing marine eutrophication as the proxy, we can gauge the broader ecological impact of pollutant emissions on these vital systems. Furthermore, studying marine eutrophication as a proxy offers a tangible link between pollutant emissions and observable environmental consequences. This can enhance public awareness and policy discussions, as it provides a direct illustration of how human actions can detrimentally affect marine ecosystems. In an era of growing global population and intensified agriculture due to industrialization, nutrient emissions to water have escalated. Progress toward sustainable nutrient usage entails mitigating eutrophication and disentangling it from human and economic development, as measured by the GDP.

An inclusive evaluation encompasses both domestic marine eutrophication and the marine eutrophication footprint associated with supply chains of consumed goods and services to gauge advancement. Furthermore, per capita pollution has also been considered.

2.1.4. Material Use

The term "material" comprises several main categories and their respective sub-categories, which collectively encompass a wide range of natural resources used across diverse industries and economic activities. These categories include biomass, metal ores, non-metallic minerals, and fossil fuels (non-energy use only), each with sub-categories that reflect specific types of materials and their applications within various sectors [2,31]. This classification system provides a comprehensive framework for understanding the intricate material flows and resource utilization patterns within an economy [32]. In this analysis, we inspected the countries considering three key dimensions: raw material use, material use per capita, and material productivity. These facets offer a comprehensive view of how these nations navigate the ever-evolving landscape of material utilization. Domestic material consumption (DMC) was selected to assess the material consumption patterns of the concerned countries. The assessment was performed using three indicators: DMC, DMC per capita, and material productivity. DMC is a fundamental indicator in the field of material flow accounting, serving as a crucial measure to assess material usage within a national economy. The indicator mainly focuses on the territorial aspect of the economy. It quantifies the consumption of materials, reflecting the total volume of materials utilized within the country's boundaries for various economic activities. In essence, DMC captures the physical dimensions of economic interactions and processes, making it an important tool for analyzing natural resource consumption within a country's production sector. Per-capita material use, also called the metabolic profile, is a related concept that expresses the average level of material consumption per person within the economy. This metric provides insights into the environmental pressures associated with the country's material use patterns [2,33]. Material productivity refers to the measure of how efficiently raw materials or resources are used in the production of goods and services. It quantifies the relationship between the output (economic value created) and the input (quantity of raw materials or resources used) in a production process. In essence, material productivity assesses the ability of an economy or a production system to generate more economic output with fewer material inputs, thereby minimizing waste, reducing the environmental impact, and maximizing resource efficiency [34]. Considering both domestic material consumption (DMC) and the material footprint (MF) is crucial, as they address distinct facets of the economy: DMC pertains to production, whereas MF relates to consumption. This is especially significant because a country's DMC might be influenced by factors such as primary production or outsourcing material-intensive processes. While DMC measures the actual material utilization within the country's borders, MF accounts for the virtual material requirements across the entire supply chain needed to fulfill the final demand [2,35]. Furthermore, it is also imperative to decouple a nation's economic advancement from its consumption of raw materials. This separation is effectively achieved when the growth rate of a country's gross domestic product surpasses the growth rate of its overall material utilization. This signifies that economic progression is no longer inextricably linked to the escalated consumption of resources, but rather it outpaces and renders more efficient utilization of materials across the spectrum of production processes.

2.1.5. Energy Use

The dataset used incorporates information encompassing the production of primary energy derived from a diverse array of energy carriers. A total of 21 distinct energy products were considered and subsequently assigned to particular sectors within the global input–output tables. To facilitate more effective communication and analysis within the SCP-HAT database, these energy products were then categorized into six distinct groups: (1) coal and peat, (2) oil and natural gas, (3) nuclear energy, (4) solid biofuels, (5) captured energy sources (e.g., hydro, geothermal, solar), and (6) heat. This categorization scheme streamlines the presentation and interpretation of data, contributing to a more comprehensive understanding of the energy production dynamics. In the present analysis, energy use, per capita consumption, and energy productivity, assessed in terms of GDP, were analyzed to evaluate the societal energy requirements while considering the production and consumption perspectives. The information related to domestic primary energy considering the production and consumption perspectives was provided over a period of 1990 to 2018. The data were presented for total primary energy (production and consumption) measured in terms of terajoules (TJ) for China, India, Indonesia, Pakistan, Thailand, and Vietnam. Furthermore, primary energy production and consumption trends were also analyzed in terms of GDP and a per capita basis.

2.1.6. Water Use

For species and ecosystems to survive, water is a crucial resource. Agriculture and many other economic activities depend on it as well. To guarantee that the requirements are satisfied, and water scarcity and droughts are avoided or lessened, inclusive water management is required, particularly in situations when the local water availability is insufficient to meet the demand. The SCP-HAT dataset provides national water consumption data, encompassing water extracted from surface water or groundwater, which is subsequently either incorporated into the manufacturing of products or evaporated during the growth phase of crops or the production processes of goods. In SCP-HAT, the data by Pfister et al. [36], specifically for the year 2000, were aligned with country-level and sector-level details, following the methodology outlined by Lutter et al. [37]. Additionally, time series data were constructed based on a regionalized version of EXIOBASE 3, as detailed in the work by Cabernard et al. [38]. This comprehensive approach allows for a robust assessment of water consumption across different regions and sectors, offering valuable insights into the sustainability of consumption and production practices on a national scale. To measure the water needs of society while taking into account the production and consumption perspectives, the water usage, per capita consumption, and water productivity assessed in terms of GDP were examined.

2.1.7. Decoupling Factor

The decoupling factor was also measured, which helps to gauge the relationship between economic growth and a particular indicator, such as energy consumption or greenhouse gas emissions, etc. It implies whether economic growth is occurring independently of that indicator, or if they are still linked with respect to the baseline values. The formula to calculate the decoupling factor is [33]:

$$Decoupling\ factor = DF = 1 - \frac{Indicator\ value\ (t)/Economic\ output\ (t)}{Indicator\ value\ (0)/Economic\ output\ (0)}$$

where the economic output is defined in terms of GDP over a considered period (i.e., between 1990 and 2018). The baseline year and the year of comparison are specified as ‘0′ and ‘*t*’, respectively. The year 1990 was chosen as a baseline for the present analysis. The indicator value (e.g., energy consumption, CO_2 emissions) is also considered over the same period. The interpretation of the decoupling factor depends on its value, as follows:

Positive decoupling factor (>0)—This indicates that economic growth is happening at a faster rate than the growth of the environmental indicator. It suggests that economic activity is becoming more efficient in terms of resource use or environmental impact with respect to the baseline values.

Negative decoupling factor (<0)—This implies that the growth of the environmental indicator is outpacing the economic growth. It suggests that economic activity is becoming more resource-intensive or environmentally impactful with respect to the baseline values.

It is worth noting that the decoupling factor holds a relative nature and fails to encompass all the intricacies of the interplay between economic growth and the specific indicator under consideration. On the other hand, the productivity or intensity trends could serve the purpose of identifying the absolute decoupling.

2.2. Linking the Indicators with SDGs

The SDGs encompass a set of 17 ambitious objectives established by the United Nations with the intention of addressing global environmental, economic, and social challenges. Countries are dedicatedly working toward achieving these targets by the year 2030. The indicators selected in this study address various SDGs and their specific targets. These indicators could play a pivotal role in accurately gauging the performance of these goals, facilitating well-informed decision-making. Inspired by the Life Cycle Initiative (2023), each selected indicator was, therefore, linked with the relevant SDGs (see Table 1). However, no scoring has been undertaken. The process of associating indicators with their corresponding SDGs aids in assessing the progress of individual SDGs—whether they are being realized, lagging, or exhibiting satisfactory advancement [39].

Table 1. Sustainable Development Goals' (SDGs) relevance to the selected indicators [40].

Indicator	SDGs	SDG Targets
Climate change	13 CLIMATE ACTION	Target 13.1: Strengthen resilience and adaptive capacity to disasters. Target 13.2: Integrate climate change measures into policy and planning. Target 13.3: Capacity building through knowledge and awareness. Target 13.a: Implement commitment undertaken by developed parties. Target 13.b: Promote mechanisms to raise capacity for management.
Marine eutrophication	6 CLEAN WATER AND SANITATION	Target 6.3: Improving water quality by reducing pollution. Target 6.6: Protect and restore water-related ecosystems. Target 6.a: Expand international cooperation. Target 6.b: Strengthen the participation of local communities.
	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Target 12.2: Sustainable and efficient use of natural resources. Target 12.4: Waste management.
	14 LIFE BELOW WATER	Target 14.1: Reduce marine pollution. Target 14.2: Protect marine and coastal ecosystems. Target 14.c: Enhance the conservation and sustainable use of oceans.
Biodiversity loss	15 LIFE ON LAND	Target 15.1: Sustainable use and conservation of ecosystems. Target 15.2: Sustainable management of all types of forests. Target 15.5: Take significant action to reduce the habitats' degradation. Target 15.9: Integrate ecosystem and biodiversity values into national and local planning.

Table 1. *Cont.*

Indicator	SDGs	SDG Targets
Material use	8 DECENT WORK AND ECONOMIC GROWTH	Target 8.1: Sustain per capita economic growth. Target 8.2: Attain higher economic productivity. Target 8.4: Improve resource efficiency in consumption and production and endeavor to decouple economic growth from environmental degradation.
	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Target 12.2: Efficient resource management. Target 12.7: Promote sustainable public procurement practices.
Energy use	7 AFFORDABLE AND CLEAN ENERGY	Target 7.1: Access to affordable and modern energy. Target 7.2: Increase renewable sources in energy mix. Target 7.3: Improve the energy efficiency.
	9 INDUSTRY, INNOVATION AND INFRASTRUCTURE	Target 9.2: Promote inclusive industrialization.
	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Target 12.2: Efficient and sustainable use of natural resources.
	13 CLIMATE ACTION	Target 13.2: Integrate national policies to combat climate change.
Water use	6 CLEAN WATER AND SANITATION	Target 6.1: Safe and affordable drinking water. Target 6.3: Improve water quality, wastewater treatment, and safe reuse. Target 6.4: Increase water use efficiency and ensure freshwater supplies. Target 6.5: Implement integrated water resources' management. Target 6.6: Protect and restore water-related ecosystems.
	12 RESPONSIBLE CONSUMPTION AND PRODUCTION	Target 12.2: Efficient resource management. Target 12.4: Waste management.
	14 LIFE BELOW WATER	Target 14.1: Reduce water pollution of all kinds. Target 14.2: Protect marine and coastal ecosystems. Target 14.c: Enhance the conservation and sustainable use of water resources.

2.3. DPSIR Analysis

The chosen indicators served as the basis for assessing and overseeing the performance of the SDGs using the DPSIR framework. This framework holds substantial utility in policy analysis, aiding in comprehending the drivers and pressures, evaluating their condition and impacts, and formulating appropriate responses. The drivers encapsulate socio-economic and socio-cultural forces steering human activities, while the pressures signify the strains imposed on the environment. The state pertains to the environmental well-being, and impact refers to the repercussions of environmental deterioration. Correspondingly, the responses delineate society's reactions to specific environmental circumstances [41,42].

3. Results and Discussion

This section delves into the results and discussions that stem from an in-depth analysis of the interplay between regional as well as global issues, such as the triple planetary crisis, resource efficiency, and the paradigm of sustainable consumption and production. Through a comprehensive analysis of data projections and trends, this section aims to explore the relationships and identify critical factors, all with the overarching goal of contributing to sustainable advancement within the Asian region.

3.1. Climate Change

Through Sustainable Development Goal 13 (Climate action), the United Nations has warned that climate change has become a global concern, impacting nations across all continents. This phenomenon disrupts national economies and poses a significant threat to developmental pursuits. A comprehensive analysis of the GHG historical data and future projections until 2030 by six Asian countries—China, India, Indonesia, Pakistan, Thailand, and Vietnam—along with their carbon neutrality and/or net-zero targets, is provided in Figures 2 and 3.

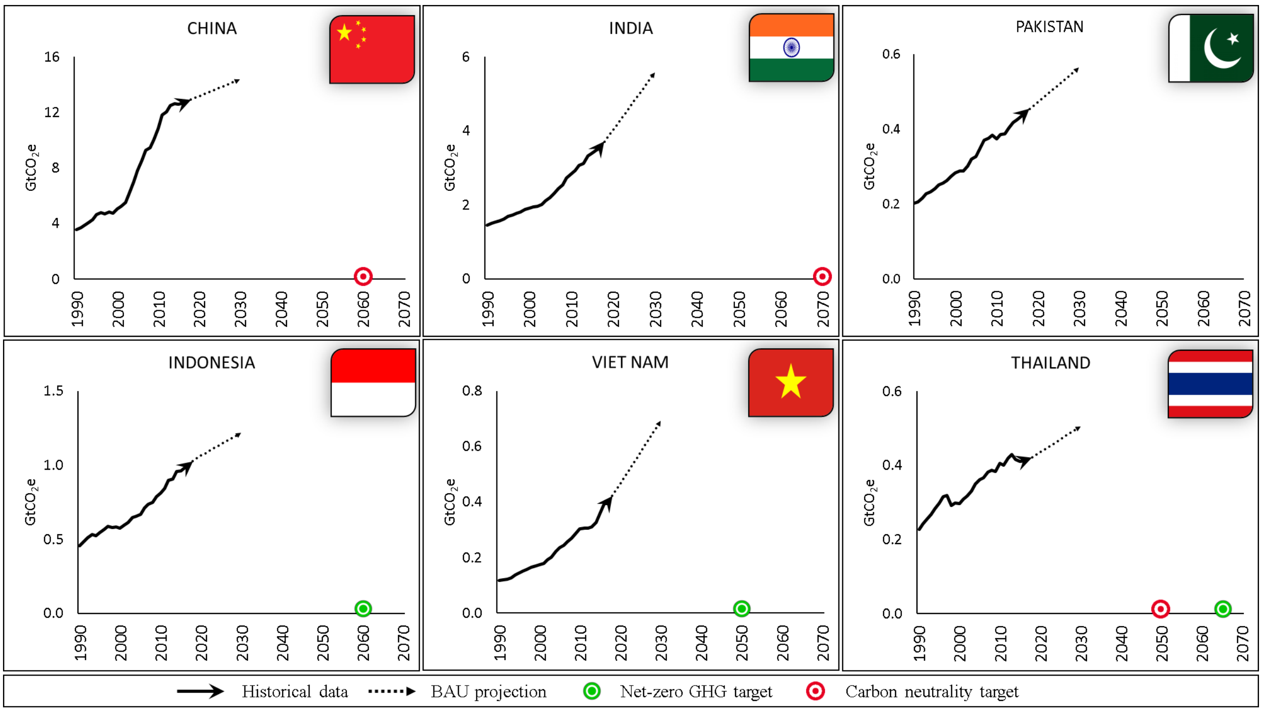

Figure 2. GHG emission trajectories implied by business-as-usual (BAU) and net-zero targets.

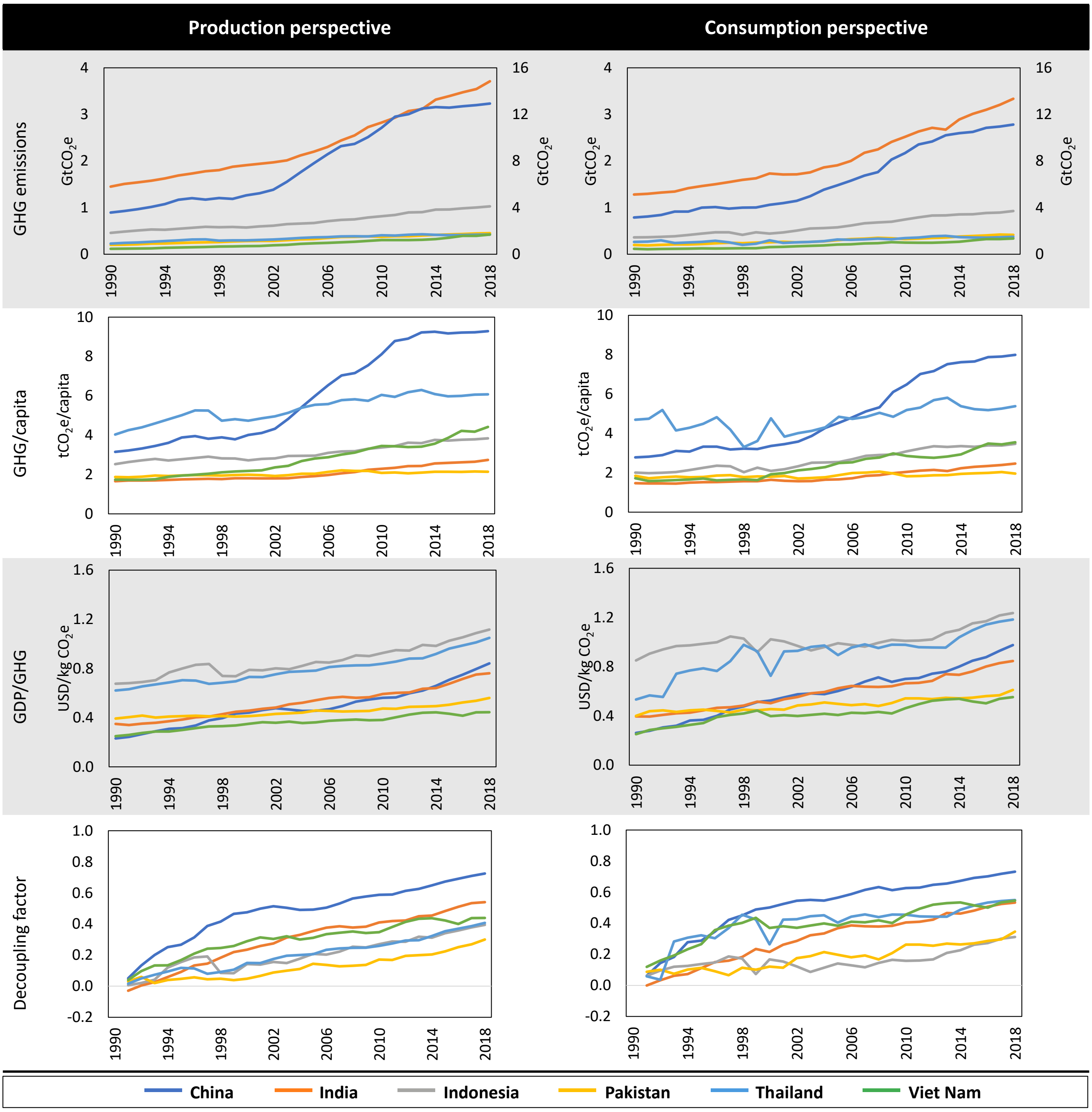

Figure 3. Total GHG emissions (only China on the secondary axis), GHG per capita, GDP per GHG, and decoupling factor considering the consumption and production perspectives.

NDCs are voluntary commitments made by countries under the United Nations Framework Convention on Climate Change (UNFCCC) to combat global climate change; the key progress updates, targets, and mitigation strategies, provided by each country in their NDC submissions, have also been highlighted. Globalization and worldwide supply networks increase the spatial distribution of environmental pressures and impacts linked with the production and consumption of traded goods. Thus, China is responsible for GHG emissions across the globe through its international trade linkages. The domestic GHG emissions in China (production perspective) increased from 3.6 $GtCO_2e$ in 1990 to 12.9 $GtCO_2e$ in 2018 and are expected to reach 14.4 $GtCO_2e$ in 2030 while following the BAU, as shown in Figure 2. On the other hand, the carbon footprint of China increased by

252.6% from 1990 to 2018, reaching 11.1 $GtCO_2e$ in 2018. The per capita carbon footprint in China, i.e., 8.0 tCO_2e/capita, exceeds the global average, which stands at 6.2 tCO_2e/capita in 2018 [43]. At the sub-regional level, the per capita carbon footprint of China is in close alignment with the regional average for East Asia and the Pacific, which is approximately 7.6 tCO_2e/capita. On the other hand, the regional average for South Asia is significantly lower at 2.3 tCO_2e/capita, compared to China. This demonstrates a notable disparity in carbon emissions between China and South Asia, with China emitting considerably more carbon per person than the South Asian region overall. Considering the GHG emissions in terms of economic growth (measured in GDP) showed that China achieved relative decoupling between 1990 and 2018. China's updated NDC aims to peak carbon emissions before 2030 and achieve carbon neutrality before 2060, as shown in Figure 2. For this purpose, China must peak the consumption of fossil resources such as coal, oil, and gas by 2025, 2030, and 2035, respectively [44]. Furthermore, China is aiming to reduce its carbon intensity per unit of GDP by 65% from the 2005 levels, increasing non-fossil-fuel consumption to around 25% of primary energy, and enhancing the forest stock volume by 6 billion cubic meters by 2030.

The GHG impacts in India increased from 1.5 $GtCO_2e$ in 1990 to 3.7 $GtCO_2e$ in 2018. During the same period, the carbon footprint of India increased by 160% to 3.3 $GtCO_2e$ in 2018. India has also achieved relative decoupling of GHG emissions from its economic growth; however, absolute decoupling still seems unrealistic. The per capita carbon footprint of India (i.e., 2.5 tCO_2e per capita) is considerably lower than the global and East Asia and Pacific averages; however, it is almost the same as the average of South Asia [43]. India's updated NDC targets a 45% reduction in the emission intensity of its GDP by 2030 from the 2005 levels. It aims to achieve about 50% of its electric power capacity from non-fossil-fuel sources by 2030 and create an additional carbon sink of 2.5 to 3 billion tonne of CO_2 equivalent through forest and tree cover. The country's NDC plans to reduce unconditional emissions by 31.9% and conditional emissions by 43.2% by 2030, compared to the business-as-usual scenario. It focuses on land use planning, sustainable forest management, improved agriculture productivity, energy conservation, and increased use of clean and renewable energy sources.

Despite contributing only 0.9% to the global greenhouse gas emissions, Pakistan is among the countries that are most vulnerable due to the effects of climate change [45]. Considering the final consumption in the country, Pakistan was responsible for 415.7 $MtCO_2e$ of GHG emissions in 2018. The carbon footprint of Pakistan increased by 109.6% from 1990 to 2018. Pakistan also achieved relative decoupling of its economy from GHG emissions during this period. The per capita carbon footprint of Pakistan (2.0 tCO_2e per capita) is far less than the global and East Asia and Pacific average values; however, it is almost the same as the regional average of South Asia [43]. Pakistan intends to reduce its projected GHG emissions by 50% (15% unconditionally and 35% conditionally) below the business-as-usual levels by 2030. It seeks international financial support to achieve the additional reduction. Unlike other selected countries, Pakistan has not declared a zero-carbon year. In the short term, Pakistan's Nationally Determined Contribution (NDC) is ambitious, pledging to cut 50% of the projected emissions and reach 60% renewable energy by 2030.

The carbon footprint of Indonesia increased by 155% between 1990 and 2018, accounting for 927.7 $MtCO_2e$ in 2018. Indonesia also achieved relative decoupling of its economy from GHG emissions during the period of the last three decades. The per capita carbon footprint of Indonesia is around 3.5 tCO_2e, which is almost 44% below the global average and approximately 55% below the East Asia and the Pacific regional averages [43]. Indonesia upped its unconditional emission reduction target from 29% in the first NDC to 31.89% in the enhanced NDC [46]. This dedication is executed via proficient land utilization and spatial arrangement, the implementation of sustainable forest administration, encompassing a program for social forestry, the reinstatement of functionalities within deteriorated ecosystems, such as wetland ecosystems, enhanced agricultural efficiency, energy preservation, the advancement and advocacy of clean and renewable energy sources, as well as an enhancement in waste management practices. Indonesia announced to conditionally increase its commitment to a 43.2% reduction in emissions by 2030, up from 41% in the first NDC, subject to the availability of international support for finance, technological transfer and development, and capacity building.

The GHG emissions in Thailand increased by 85.1%, from 227.8 $MtCO_2e$ in 1990 to 421.7 $MtCO_2e$ in 2018. The carbon footprint of Thailand increased by 40.8% during the considered period, reaching 373.7 $MtCO_2e$ in 2018. The per capita carbon footprint of Thailand is around 5.4 tCO_2e per capita, which is considerably lower than the global average (6.2 tCO_2e per capita) and the average value for East Asia and the Pacific (7.6 tCO_2e/capita); however, the per capita carbon footprint for Thailand is significantly higher than the South Asian average [43]. The main source of GHG emissions was the energy sector, accounting for 67% of the total emissions in 2000, slightly increasing to 69% in 2018 [47]. During the same period, the share of the agricultural sector fell from almost 20% in 2000 to 16% in 2018, while the shares of Industrial Processes and Product Use (IPPU) and waste sectors remained almost the same, from 4.26% in 2000 to 4.48% in 2018. Furthermore, Thailand aims to reduce greenhouse gas emissions by 20% unconditionally and up to 25% with international support from the projected business-as-usual levels by 2030 [48], with an emphasis on technology access, financial resources, and the development of capabilities. Moreover, Thailand has also devised its Long-term Low Greenhouse Gas Emission Development Strategy (LT-LEDS), steering the nation toward a trajectory of low carbon development characterized by climate resilience. This strategy serves as a foundational framework for augmenting the forthcoming Nationally Determined Contributions [47].

The GHG emissions in Vietnam increased by 257.4%, from 118.1 $MtCO_2e$ in 1990 to 422.0 $MtCO_2e$ in 2018. The carbon footprint of Vietnam increased by 189.5% during the same period, accounting for 339.2 $MtCO_2e$ in 2018. The per capita carbon footprint of Vietnam (3.6 tCO_2e per capita) is 42% below the global average, which is 6.2 tCO_2e per capita [43]. The decoupling of economy from the GHG emission is not significant as compared to the other considered countries. Vietnam's Nationally Determined Contributions delineate an objective of reducing emissions by 7.3% vis-à-vis the business-as-usual by 2025, concurrently striving for an unconditional 9% reduction in total greenhouse gas emissions relative to the BAU projection by 2030. This aforementioned 9% reduction ambition can be elevated to 27% by 2030, subjected to conditional international support and the utilization of market and non-market mechanisms, as per Article 6 of the Paris Agreement [49].

In summary, the available trends offer insight into the evolving connection between greenhouse gas (GHG) emissions, economic and population growth, and trade dynamics for six countries—China, India, Indonesia, Pakistan, Thailand, and Vietnam—spanning almost three decades. Notably, a trend emerges wherein these nations progressively work to decouple economic expansion from the GHG emissions. The initial years exhibited modest or even negative decoupling values, as shown in Figure 3, indicating a direct link between growth and emissions. However, as time unfolds, a positive shift becomes evident, with most countries displaying a move toward reduced dependency on emissions for economic advancement. This shift implies the adoption of cleaner technologies, policy reforms, and a broader sustainability agenda. Although variations exist, the overall pattern signifies concerted efforts to harmonize prosperity with environmental preservation, underscoring the significance of continued strategic actions to ensure lasting sustainable development. On the other hand, achieving absolute decoupling, where economic growth is completely detached from greenhouse gas emissions, is confronted with formidable challenges that also make it an impractical goal in the present context. Historical trends, energy transition challenges, carbon-intensive economic structures, global economic disparities, consumer behavior complexities, intricate systems, and policy coordination issues all contribute to the impracticality of absolute decoupling. The complexities of technology, economic systems, and international cooperation make relative decoupling in line with sustainability objectives, where emissions grow slower than economic growth, a more achievable and pragmatic approach in the immediate term.

3.2. Biodiversity Loss

Societies depend on land for various purposes, such as agriculture, forestry, and urban areas. However, practices such as soil sealing and intensive agriculture limit the land's ecological function, causing biodiversity loss [43]. Sustainable Development Goal 15 (SDG 15) emphasizes conserving biodiversity, sustainable ecosystem use, and responsible land and forest management. This involves reducing land demand for production to avoid competition. Besides domestic land use, countries also depend on global land resources through trade, collectively known as the land footprint.

The ongoing worldwide extinction event, often termed the sixth mass extinction or the Anthropocene extinction, was instigated by human actions that exceed the limits of Earth's ecological capacity and has, thus far, displayed an irreversible trajectory, resulting in a critical biodiversity crisis [50]. Biodiversity loss encompasses the global extinction of diverse species and the localized decline or disappearance of species within specific habitats, leading to a diminishment of biological diversity [51]. The latter occurrence can be of a transient or enduring nature, contingent upon whether the environmental deterioration causing the loss can be remedied through ecological restoration or resilience, or if it is enduringly irreversible, such as due to land degradation [51,52]. Land is a foundational natural resource that underpins a nation's economic prosperity. It serves as the origin of all material wealth and profoundly influences agriculture, trade, and industry. The availability of resources within the land, such as fertile soil and energy sources, shapes a country's economic trajectory. In essence, land's role in determining a nation's livelihood and economic well-being is paramount [53]. Overexploitation of land can lead to dire consequences for both human societies and ecosystems. Excessive land use can result in soil degradation, erosion, and a loss of fertility, undermining agricultural productivity and food security. Land use change is the alteration of the natural landscape due to human activities, focusing on the functional role of land for economic purposes. These changes can be complex, impacting living conditions and vulnerability [54]. Land use change is considered as the main driver of biodiversity loss; therefore, assessing change trajectories and projecting future conditions are crucial for sustainability [54,55].

In the analysis, both the production and consumption sides of potential species loss from land use indicate significant impacts in terms of biodiversity loss across the studied countries (see Figure 4). On the production side of potential species loss from land use, it is evident that each of the six countries (China, India, Indonesia, Pakistan, Thailand, and Vietnam) experienced varying degrees of fluctuation in their indicators over the studied period (1990–2018). These fluctuations were characterized by significant percentage increases and, in some cases, notable reversals. China witnessed a noteworthy increase in potential species loss from land use during the initial years, with a 7.2% rise from 4.8 milli-PDF*year in 1990 to 5.1 milli-PDF*year in 2011. This increase was followed by a period of relative stability. Similarly, India displayed an overall upward trend of approximately 16.3%, from more than 5.9 milli-PDF*year in 1990 to around 7 milli-PDF*year in 2011. However, the subsequent years showed fluctuations, with a decline to 6.9 milli-PDF*year in 2013. Indonesia's potential species loss from land use exhibited dramatic fluctuations, witnessing a remarkable 23.9% increase from around 6.5 milli-PDF*year in 1990 to 8.1 milli-PDF*year in 1998. This increase was followed by a substantial reversal, plummeting to 7 milli-PDF*year in 2013, which represents a notable 13.3% decline from its peak. Pakistan experienced fluctuations throughout the studied period. Notably, the country observed a striking 43.4% increase from 0.21 milli-PDF*year in 1990 to 0.3 milli-PDF*year in 2001, followed by a notable decline to 0.19 milli-PDF*year in 2018, representing a significant decrease of 36.1% from the peak. Thailand's potential species loss from land use displayed a less volatile pattern, with fluctuations around a relatively stable range. Vietnam, on the other hand, demonstrated a gradual increase of approximately 57.3%, from 0.49 milli-PDF*year in 1990 to 0.87 milli-PDF*year in 2018.

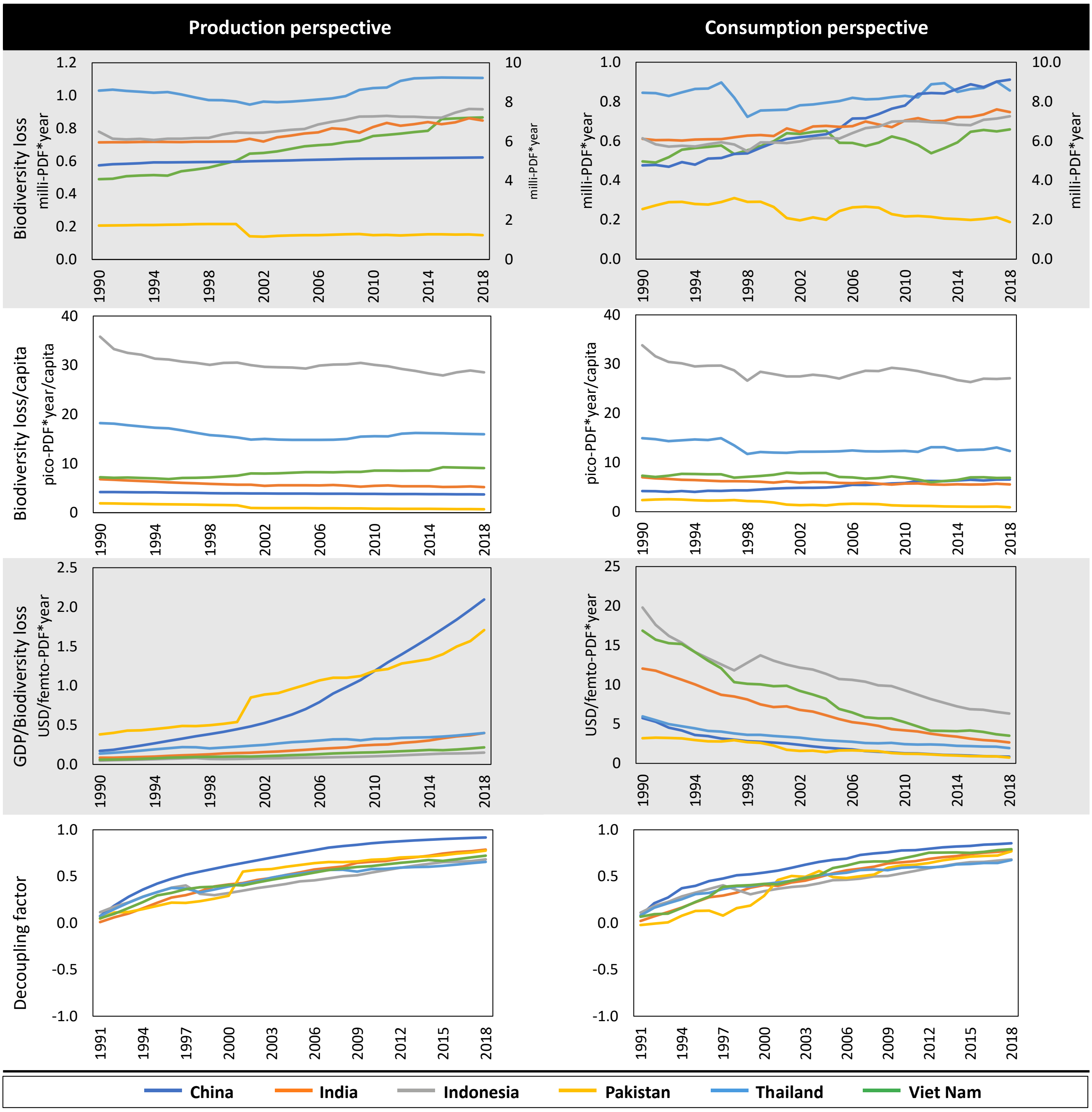

Figure 4. Potential species loss from land use change (only China on the secondary axis), potential species loss per capita, GDP per potential species loss, and decoupling factor considering the consumption and production perspectives.

On the consumption side, the data revealed notable trends and fluctuations in potential species loss from land use across the six countries. Pakistan displayed a remarkable reduction of 25% in potential species loss from 1990 to 2018, whereas Thailand exhibited a rather consistent trend, with a slight increase of less than 1.5%. This is because both Pakistan and Thailand are agriculture-based economies, as reflected in their top exports, which are mostly agricultural or agroindustry-based products [56,57]. Agriculture constitutes a significant utilization of land resources, occupying approximately half of the Earth's habitable land. This extensive land allocation exerts a substantial influence on the global environment by diminishing natural wilderness areas and posing a direct challenge to biodiversity preservation [58]. Pakistan's top exports include rice and textiles, while Thailand is the world's biggest exporter of rubber, exotic fruits, starches, cassava, and processed meat. Pakistan mostly exports to countries including the USA, China, Germany, the UK, and the UAE, while Thailand exports to the USA, China, Japan, Vietnam, and Australia. On the other hand, the top imports of both Pakistan and Thailand are mostly petroleum products [56,57]. The petroleum sector is comparatively less land-intensive as compared to agriculture; therefore, both Pakistan and Thailand are net exporters of land. Indonesia, on the other hand, encountered considerable fluctuations, with an initial decrease of 5% by 1992, followed by a modest increase of more than 18% by 2018. Taking a brief look into Indonesia's import and export profile, it becomes evident that the country holds the distinction of being the largest global importer of soybean, while simultaneously holding the position of the world's leading exporter of palm oil [59]. Both soybean and palm oil are agricultural products; however, comparatively higher environmental burdens are associated with soybean. While it produces a lower oil yield per hectare compared to palm oil, a significant portion of its yield is dedicated to high-protein animal feed, minimizing waste. Additionally, soybean oil demands a greater quantity of fertilizers, pesticides, and energy input per hectare [60]. From 1990 to 2018, Vietnam and India experienced a more substantial rise of around 33% and 23%, respectively. Vietnam engages in a trade dynamic where identical goods hold significance in both imports and exports. Notably, products such as coconuts, Brazil nuts, and cashews, along with light rubberized knitted fabric, feature prominently in both categories. Importantly, Vietnam's dominant position is evident in its imports of these agricultural and agroindustry-based goods, underscoring its dependence on land-intensive products from the global market, also evident from the observed trends. Vietnam preliminarily sources these imports from China, South Korea, Japan, Chinese Taipei, and Thailand [61]. On the other hand, India's trade landscape exhibits substantial agricultural product exchanges in both exports and imports. Notably, India ranks as a significant exporter of rice, while being a substantial importer of palm oil and soybean oil. These exchanges involve key trade partners such as the United States, the United Arab Emirates, and China for exports, and China, the United Arab Emirates, and Switzerland for imports [62]. China witnessed a significant overall increase of 91% in potential species loss from land use. This is because of China's reliance on minerals and energy resources, importing crude petroleum, iron ore, and petroleum gas mainly from South Korea, Japan, and the United States. Additionally, China's significant import of soybeans highlights its dependence on global agriculture and mining sectors, which are both land-intensive. On the other hand, China's major exports include technology goods such as broadcasting equipment, computers, and integrated circuits, primarily to the United States and Hong Kong [63].

The trade patterns of these countries heavily relying on agricultural goods highlight their dependence on the land-intensive agriculture sector. Imports and exports of these land-intensive goods are intricately linked with their economic growth. The economic indicators, such as the intensity of biodiversity loss from land use and the decoupling factor, are essential for analyzing the connection between biodiversity loss from land use and economic growth. These indicators provide insights into how economic activities impact biodiversity and environmental sustainability, allowing policymakers to make informed decisions for fostering sustainable economic development.

Examining the production and consumption sides' intensity of biodiversity loss from land use indicators revealed intricate trends across the six countries. A comprehensive examination of these trends, encompassing percentages, fluctuations, and underlying reasons, underscores the nuanced relationship between economic activity and ecological impact. In China, the potential species loss from land use exhibited a gradual decrease of around 85% from 1990 to 2018. Similarly, India experienced a substantial decline of approximately 78%

during the same period. Indonesia, however, encountered notable fluctuations in potential species loss, with an initial decrease of 5% by 1992, followed by an increase of over 18% by 2018. In contrast, Thailand showcased a relatively consistent trend, with a marginal increase of less than 1.5% over nearly three decades. This stability can be linked to sustained agricultural practices and efforts to maintain ecological balance. Pakistan demonstrated a consistent reduction in potential species loss, witnessing a remarkable decrease of 25% from 1990 to 2018. This decline may have stemmed from measures to optimize land use and minimize the ecological impact, such as the launch of the first National Land Use Plan Project that was initiated in 2004 [64]. In Vietnam, however, a substantial increase of around 33% in potential species loss occurred during the same period. In terms of percentages, China and India lead in reducing the potential species loss, showcasing their commitment to sustainable development. Meanwhile, Indonesia and Vietnam grapple with fluctuating trends, reflecting the complexity of balancing economic growth and ecological conservation. Pakistan's consistent reduction in potential species loss signifies a progressive approach to land use, while Thailand's marginal increase underscores the need for ongoing efforts to safeguard biodiversity.

The observed fluctuations, such as Indonesia's oscillation and Vietnam's rise, can be attributed to dynamic factors, including shifts in land allocation, changing consumption patterns, and policy adjustments. Rapid economic growth might lead to an increased demand for land-intensive products, contributing to biodiversity loss. Furthermore, global market dynamics and trade relationships influence these trends, as countries export and import diverse products with varying ecological footprints. To address extreme fluctuations and optimize sustainability, countries can adopt mitigation strategies encompassing sustainable land management, efficient resource utilization, and technology-driven solutions. By encouraging eco-friendly agricultural practices, promoting circular economies, and investing in clean technologies, countries can decouple economic growth from biodiversity loss. Robust policy frameworks and international collaborations are essential to foster a harmonious balance between economic prosperity and environmental preservation.

3.3. Marine Eutrophication

The nitrogen and phosphorus cycles, which have surpassed planetary boundaries, are critical aspects of concern. Addressing nutrient loss mitigation predominantly hinges on agricultural practices, intersecting with food security (e.g., SDG 2: zero hunger) and sustainable agriculture (e.g., SDG 12: responsible consumption and production). The SDG 14 (life below water) deals with the aquatic life in the marine ecosystems. The legally binding UN Water Convention of 1992 encompasses SDG 6.5 (integrated water resources management) and regional integration, aligning with the imperative of managing nutrient-related challenges.

The domestic marine eutrophication (DEU) of China increased from 0.025 to 0.056 million tonne. Overall, it increased by 82% from 1990 to 2018. The rate of increase in domestic eutrophication was highest from 2001 to 2006. However, the change of increase in domestic eutrophication showed very slight changes from 2007 to 2013 and showed a decline in trends from 2014 onward. This shows the decoupling efforts of the policymakers. However, the overall increases in DEU are mainly related to the rapid increases in population density, fertilizer application, sewage discharge, aquaculture, and fossil fuel combustion, and have resulted in distinctly increased harmful algal blooms [65]. On the other hand, the marine eutrophication footprint (MEF) increased from 88% (24 to 45 million tonne) from 1990 to 2018. In the end, a flattening of the curve was noticed. Marine eutrophication productivity (GDP/DEU) based on production increased significantly, rising from USD 23 to 233 per tonne from 1990 to 2018. This could be due to efforts to implement better agricultural practices, such as reduced fertilizer use and improved land management, which can minimize nutrient runoff from agricultural areas, improve sewage treatment plants, and ensure proper treatment of domestic and industrial wastewater, which can significantly reduce the nutrient loads entering marine ecosystems. On the other hand, the marine eutrophication productivity based on consumption (GDP/MEF) also showed a massive increase, from USD 0.03 to 0.24 per tonne. Domestic marine eutrophication per capita (DEU/capita) in China increased from 0.022 to 0.33 kg/capita from 1990 to 2018. Similarly, the marine eutrophication footprint per capita also increased from 21 to 32 kg/capita.

India had an increase in domestic marine eutrophication from 0.012 to 0.024 million tonne. From 1990 to 2018, it grew by 82% overall. Domestic eutrophication grew at the fastest pace between 2003 and 2009. However, from 2014 to 2018, the rate of change in domestic eutrophication showed a flattening trend. This demonstrates the deliberative efforts of the decision-makers. Similarly, the marine eutrophication footprint rose from 12 to 23 million tonne. Between 1990 and 2018, it grew by 93%. In the end, a flattening of the curve was seen, as shown in Figure 5. Marine eutrophication productivity (GDP/DEU) based on production significantly increased, rising from USD 43 to 118 per tonne from 1990 to 2018. This could be due to efforts to implement better policies related to nutrient management, green infrastructure, regulations and policies, and public awareness. Similarly, the marine eutrophication productivity based on consumption (GDP/MEF) also showed an increase from USD 0.04 to 0.12 per tonne, and in terms of percentage it increased by more than 187%. Domestic marine eutrophication per capita (DEU/capita) in India increased from 0.014 to 0.018 kg/capita from 1990 to 2018. Similarly, the marine eutrophication footprint per capita also increased from 13 to 15 kg/capita.

Indonesia had an increase in domestic marine eutrophication from 0.0029 to 0.0059 million tonne. From 1990 to 2018, it grew by 105% overall. Domestic eutrophication grew at the fastest pace between 1993 and 1996. However, from 2014 to 2018, the rate of change in domestic eutrophication showed a relatively low trend. Similarly, the marine eutrophication footprint increased from 3 to 6 million tonne. Between 1990 and 2018, it grew by almost 100% in percentage terms. In the end, flattening of this curve was seen as well. From 1990 to 2018, the marine eutrophication productivity (GDP/DEU) based on production dramatically increased, rising from USD 108 to 195 per tonne. Similarly, as indicated in Figure 5, the marine eutrophication productivity based on consumption (GDP/MEF) grew from USD 0.1 to 0.19 per tonne, increasing by more than 84%. From 1990 to 2018, Indonesia's domestic marine eutrophication per capita (DEU/capita) grew from 15 to 22 kg/capita. Similarly, the marine eutrophication footprint per capita rose from 16 to 22 kg/capita. The improvement in the numbers may be the result of attempts to put improved regulations and policies for nutrient management, green infrastructure, regulations, and public awareness into place.

Domestic marine eutrophication increased in Pakistan from 0.0021 to 0.0046 million tonne. It generally expanded by approximately 60% between 1990 and 2018. Between 2008 and 2010, domestic eutrophication grew at the quickest rate. However, there was a drop in the trends from 2013 to 2018. Similarly, the marine eutrophication footprint increased from 1.9 to 3.5 million tonne. It increased by around 75% between 1990 and 2018. From 1990 to 2018, the marine eutrophication productivity (GDP/DEU) based on production dramatically increased, rising from USD 34 to 55 per tonne. Considering 1990 as the base year, marine eutrophication productivity showed a 44% increase in 2018. Similarly, the marine eutrophication productivity based on consumption (GDP/MEF) grew from USD 0.040 to 0.073 per tonne, increasing by more than 84%. From 1990 to 2018, Pakistan's domestic marine eutrophication per capita (DEU/capita) grew from 0.19 to 0.22 kg/capita. Similarly, as illustrated in Figure 5, the marine eutrophication footprint per capita decreased from 18 to 16 kg/capita.

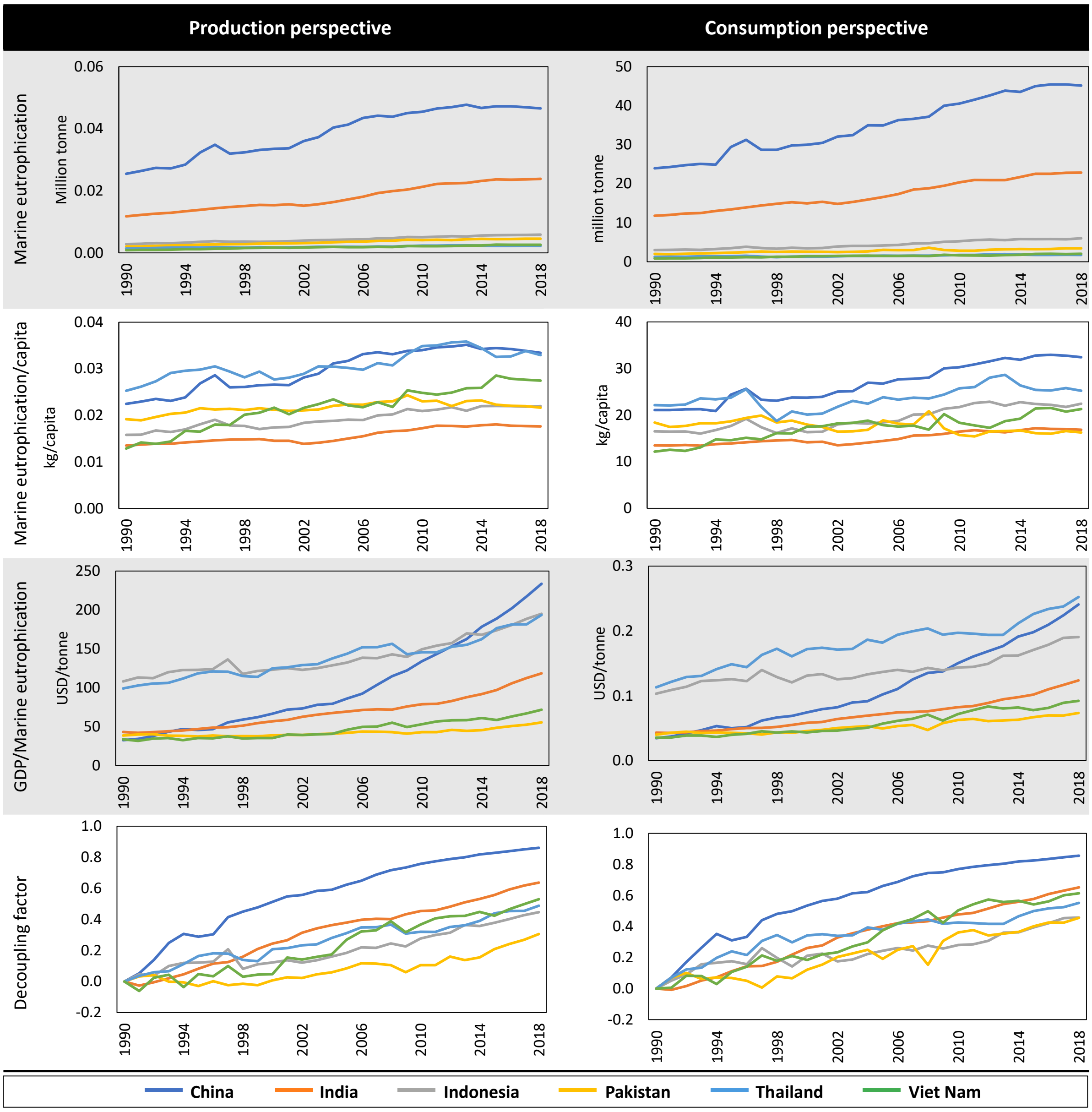

Figure 5. Marine eutrophication, marine eutrophication per capita, GDP per marine eutrophication, and decoupling factor considering the consumption and production perspectives.

Thailand had an increase in domestic marine eutrophication from 0.0014 to 0.0023 million tonne. From 1990 to 2018, it grew by 60% overall. Domestic eutrophication grew at the fastest pace between 2003 and 2009. However, 2010 to 2018 showed a sharp decline. Similarly, the marine eutrophication footprint rose from 1.2 to 1.7 million tonne. Between 1990 and 2018, it grew by almost 40% in percentage terms. From 2013 onwards, the curve showed a negative trend, as shown in Figure 5. The marine eutrophication productivity (GDP/DEU) based on output grew noticeably from USD 99 to 181 per tonne between 1990 and 2018. Marine eutrophication productivity increased by 96% in 2018 when 1990 was used as the baseline year. The marine eutrophication productivity based on consumption (GDP/MEF), which is shown in Figure 5, also rose by more than 40%, rising from USD 0.11 to 0.25 per tonne. Domestic marine eutrophication per person in Thailand increased from 0.025 to 0.033 kg/person between 1990 and 2018. Similarly, the marine eutrophication footprint per capita dropped from 22 to 25 kg/capita, as seen in Figure 5.

Vietnam had an increase in domestic marine eutrophication from 875 to 2622 tonne. From 1990 to 2018, it grew by 200% overall. Similarly, the MEF rose from 0.83 to 2.0 million tonne. Between 1990 and 2018, it grew by almost 146% in percentage terms. From 2016 onwards, the curve almost flattened, indicating that there was no significant change in marine eutrophication from 2016 to 2018, as shown in Figure 5. From 1990 to 2018, the marine eutrophication productivity (GDP/DEU) based on production dramatically increased, rising from USD 33 to 71 per tonne. Considering 1990 as the base year, marine eutrophication productivity showed a 113% increase in 2018. Similarly, the marine eutrophication productivity based on consumption (GDP/MEF) grew from USD 0.036 to 0.092 per tonne and increased by more than 146%. From 1990 to 2018, Vietnam's domestic marine eutrophication per capita (DEU/capita) grew from 0.013 to 0.027 kg/capita. Similarly, as illustrated in Figure 5, the marine eutrophication footprint per capita increased from 12 to 21 kg/capita. In conclusion, the improvements in the trends reflect the attempts to put improved regulations and policies for nutrient management, agricultural practices, regulations, and public awareness into place.

3.4. Material Use

Two specific Sustainable Development Goals, namely SDG 8, which revolves around promoting decent work and economic growth, and SDG 12, which centers on fostering responsible consumption and production, are interconnected with the overarching concept of a circular economy. This concept strives to enhance material efficiency, characterized by utilizing fewer raw materials per unit of value generated and elevating material productivity. By juxtaposing the production and consumption sides, we aimed to unravel the intricate dynamics that drive material consumption and explore potential strategies to optimize material use in the broader context of economic development, population growth, technological innovation, and policy interventions.

A common trend observed among the six countries was the general increase in raw material use over the years, reflecting growing consumption and economic activities (Figure 6). China's dominance as the highest consumer of materials is consistently noted among the six countries, indicative of its significant economic expansion [66]. Fluctuations and peaks in material use were occasionally experienced by countries such as India, Thailand, and Vietnam, despite periods of stable growth. These fluctuations in material use witnessed are multi-faceted, stemming from a combination of economic cycles, industry dynamics, policy changes, and technological shifts. The years of significant fluctuations—around 2000–2001, 2004–2005, and 2009–2010—coincide with critical junctures in these countries' economic and industrial development [67–70]. Increasing trends in material use per capita were observed across all countries, reflecting growing consumption and economic development typical during periods of industrialization and urbanization. China and Thailand stood out with the highest material use per capita among the six countries, attributed to a shift in their consumption patterns and growing resource-intensive lifestyles, potentially exacerbating ecological pressures. Vietnam, Indonesia, and India also exhibited noticeable increases in material use per capita, marking their transition toward more industrialized economies. Improvements in material productivity were consistently observed across the countries, indicating more efficient utilization of raw materials in producing goods and services. Higher material productivity is generally found in relatively higher-income countries, such as Indonesia and Thailand (when omitting China), likely resulting from better technology adoption and resource management practices. However, although China is the highest-income country among the considered countries, its lower material productivity is due to the increased material demands for higher standards of living, the push for industrialization, and the extensive infrastructure development to accommodate the highest population in the world [34]. Besides that, noteworthy is the exceptional growth in material productivity for China, as well as for India, with figures rising above 176% and 116% from 1990 to 2018, respectively. Pakistan and Vietnam have exhibited gradual improvements in material productivity, reflecting efforts to optimize manufacturing processes and embrace technological evolution [33]. When the production and consumption sides of materials are compared, interesting trade dynamics among these countries can be identified. For instance, China consistently emerged as a high producer of raw materials, and considering its role as the "world's factory", a substantial portion of these materials might be destined for export to other countries [33,71].

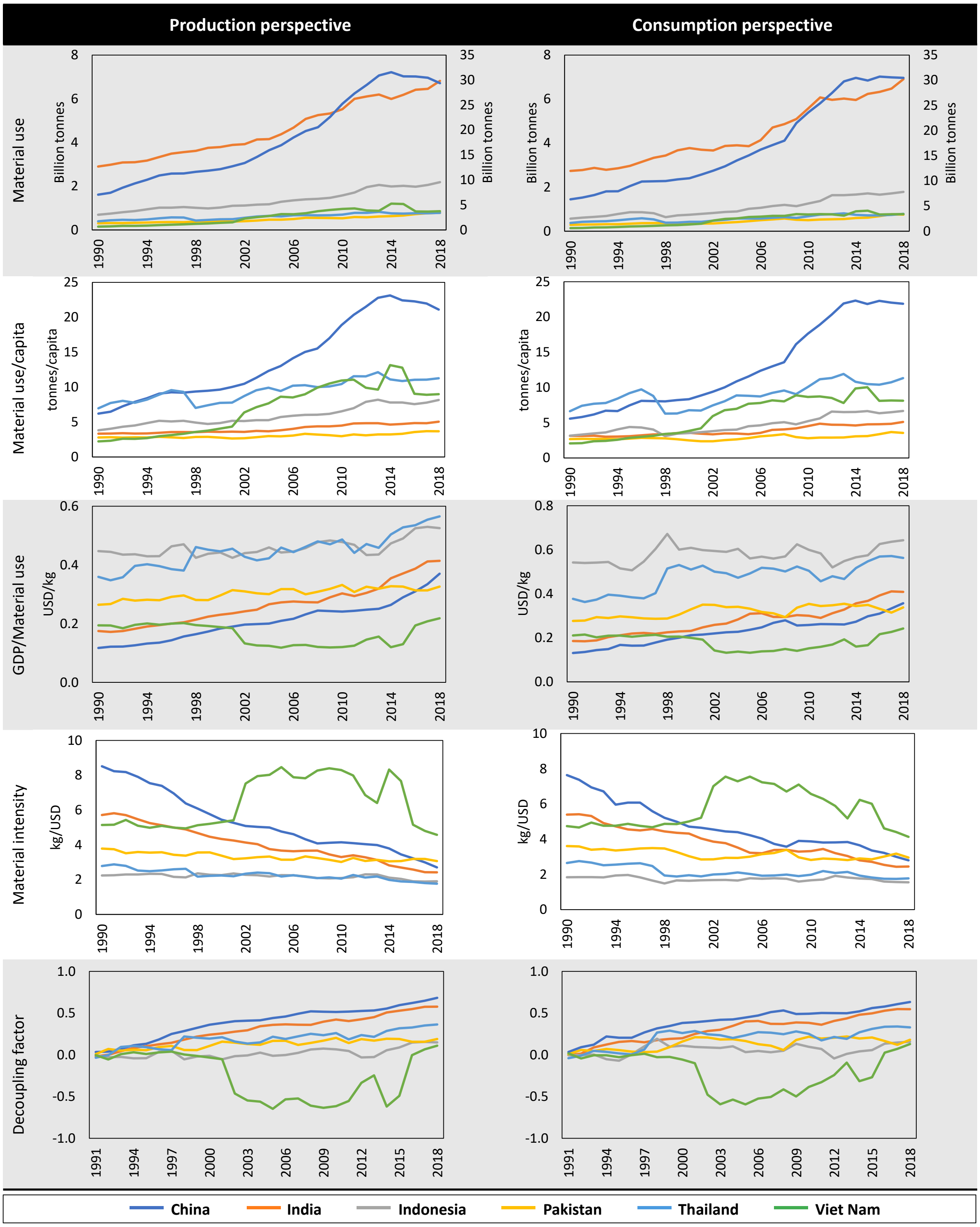

Figure 6. Total material use (China and India on the secondary axis), material use per capita, GDP per material use, and decoupling factor considering the consumption and production perspectives.

From 1990 to 2017, China's share in global merchandised trade (import plus export) increased from 2% to more than 13%, respectively [72]. On the consumption side, it can be observed that some countries might have a higher demand for materials than their domestic production can satisfy, leading to a dependency on imports. Consumption exceeding domestic production is indicated in the cases of India, Vietnam, and, surprisingly, China as well (despite the country's immense volume of exports). However, though the difference in DMC and material footprint (production and consumption sides, respectively) was nominal, it still suggests a reliance on imports to meet the material demands in China, India, and Vietnam. Economic growth is a major driver of increasing material use, as it is often accompanied by higher levels of production, consumption, and infrastructure development [34]. As economies expand, there is a greater demand for raw materials to provide feedstock for manufacturing, construction, and various other industries. Examining the relationship between economic growth and material use is crucial for understanding sustainability challenges and identifying ways to decouple resource consumption from economic expansion [33,34]. The indicators to assess the linkage between DMC and economic development are material intensity (MI) and the decoupling factor. Material intensity measures the number of raw materials used per unit of economic output (typically gross domestic product). It provides insights into the amounts of resources used to generate economic value. If material intensity decreases over time, it suggests that the economy is becoming more resource-efficient, indicating a positive trend toward decoupling economic growth from material use. Assessing the relationship between economic growth and resource use, the decoupling factor is calculated by comparing the growth rate of material use to the growth rate of GDP. A positive decoupling factor indicates that material use is increasing at a slower rate than GDP, implying progress toward more sustainable resource use [33]. Analyzing these indicators over time can reveal the extent to which economic growth is driving material consumption. If material intensity remains high and the decoupling factor is close to zero or negative, it suggests that economic growth is strongly linked to increased material use, indicating a lack of resource efficiency. On the other hand, a decreasing material intensity and a positive decoupling factor indicate successful efforts to decouple economic growth from resource consumption, signaling a more sustainable economic trajectory [33,34].

Throughout the observed years in Figure 6, China, India, and Thailand performed remarkably well in terms of lowering their material intensity on both the production and consumption sides. From 1990 to 2018, the MI in China, India, and Thailand experienced a reduction of 68%, 58%, and 36% on the production side, and 63%, 55%, and 33% on the consumption side, respectively. China, India, and Thailand demonstrated a commendable reduction in material intensity, depicting improved resource efficiency. The decoupling factor displayed periods of decoupling, implying that economic growth was, at times, less dependent on resource consumption. This indicates a positive trend toward more sustainable economic growth. Pakistan and Indonesia also showed a steady reduction in MI, accounting for 19% and 15% on the production side and 18% and 16% on the consumption side, respectively. The decoupling factor, however, showed limited decoupling in both Pakistan and Indonesia, implying that economic growth was closely linked to resource consumption and further efforts may be needed to achieve more sustained decoupling in these countries. Vietnam's MI experienced some extreme fluctuations from 2000 to 2016. In the year 2001, Vietnam's MI showed a sharp increase of 39% and 34% on the production and consumption sides, respectively. The main reason for this massive expansion in material consumption was found to be the signing of the Bilateral Trade Agreement (BTA) between the United States and Vietnam in 2000, granting the Normal Trade Relations (NTR) status, opening up access to the US market and facilitating foreign investment, driving Vietnam's shift into an export-oriented economy [73]. This trade liberalization in Vietnam, coupled with a 10-year economic plan promoting the private sector [74], contributed to the annual GDP growth, averaging 7.1% from 2000 to 2004, reaching 8.4% in 2005, and attracting global attention for its rapid economic expansion [75]. After 2015, Vietnam's MI substantially decreased, which has continued to follow the declining trend as of 2018, showing the country's efforts to decouple economic growth and material consumption.

There are some common reasons, or common drivers, causing fluctuations in material indicators across these countries. These common drivers include shifting from agrarian to industrial economies, global trade dynamics, swift adaptations to new standards due to policy shifts, environmental regulations, infrastructure development, rapidly expanding populations, and economic cycles of recession and recovery. Complex interactions between economic, policy, trade, demographic, and cyclical factors contribute to material use fluctuations, highlighting the need for sustainable resource management strategies. To optimize material use and progress sustainably, some potential strategies can be pursued, including adoption of resource-efficient production methods to reduce waste and enhance material productivity, encouraging circular practices by promoting recycling, reuse, and waste reduction, driving sustainable consumption patterns through educational efforts and awareness campaigns, investing in research for eco-friendly materials and technologies to minimize resource utilization, implementation of strong policies such as eco-labeling, extended producer responsibility, and green taxation to incentivize sustainable material use, and fostering global collaboration for sharing knowledge, transferring technology, and adopting best practices. By comprehending the drivers of fluctuations and applying these strategies, any nation can strategically optimize material use, advance sustainably, and contribute to a resource-efficient and environmentally mindful future.

3.5. Energy Use

Human well-being and economic development are a few of the key drivers of enhanced energy use. The way humans meet their energy needs has an impact on society and the global climate. SDG 7 (affordable and clean energy) and SDG 9 (industry, innovation, and infrastructure) focus on providing everyone with access to affordable, reliable, sustainable, and modern energy. Equally crucial is their role within the Paris Agreement on Climate Change, an internationally binding accord with the objective of restricting the global temperature rise to less than 2 °C above pre-industrial levels. Furthermore, in order to reduce environmental burdens, societal progress, as measured by GDP, must be decoupled from energy use. Overall, there was an increasing trend of domestic primary energy use (considering both production and consumption perspectives) across all the countries over the considered period, although the growth rates significantly varied. Further, while comparing the production and consumption sides of energy use, interesting trade dynamics could be observed among the considered countries (see Figure 7).

China consistently had the highest energy production and consumption among the listed countries, followed by India and Indonesia. China's energy production has shown consistent growth throughout the years, with a significant increase starting around the early 2000s. China's energy sector is undergoing a paradigm shift (energy revolution) and a transformation to a service-based economic model by prioritizing the electricity, natural gas, and greener, high-efficiency, and digital technologies in its energy policy [76]. The major policy interventions include the Renewable Energy Electricity Subsidy for 2023, the Hydrogen Industry Development Plan (2021–2035), and Carbon Peaking, the carbon-neutral energy sector plan. India's energy production also exhibited growth, with a notable increase from around the mid-2000s. India's energy demand is quickly increasing, with significant ramifications for the global energy industry. The Indian government has achieved significant success in providing access to electricity and clean cooking, while also pursuing a variety of energy market reforms and integrating a large proportion of renewable energy sources into the grid. The major policy interventions include the National Green Hydrogen Mission, the National Policy on Biofuels (2022 Amendment), and the Indian Railways Energy Efficiency Plan. Likewise, Indonesia, Pakistan, Thailand, and Vietnam also showed upward trends.

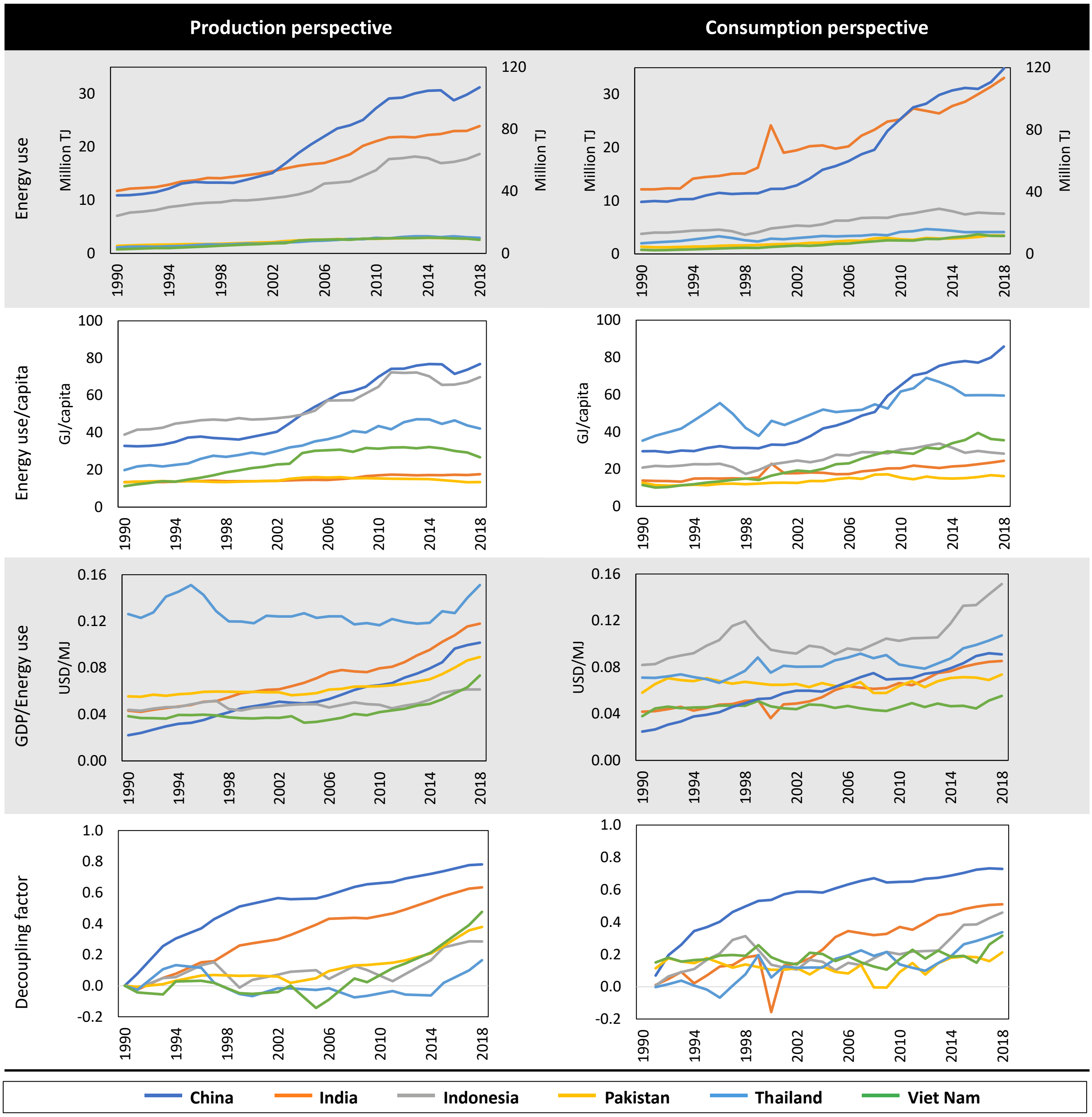

Figure 7. Total primary energy (only China on the secondary axis), primary energy per capita, energy productivity, and decoupling factor considering the consumption and production perspectives.

Over the years, there were fluctuations in energy consumption per capita for all the countries. These fluctuations could be attributed to various factors, such as economic growth, changes in energy policies, population growth, and technological advancements. China showed a significant increase in the energy footprint per capita from around 30 GJ/capita in 1990 to over 85.6 GJ/capita in 2018. This could be indicative of China's rapid industrialization and economic growth during this period. However, the growth rate seemed to stabilize after the mid-2000s. On the other hand, the comparison of the per capita energy footprint of China (85.8 GJ per capita) with the global average (78.2 GJ per capita) showed a considerable difference [43]. Furthermore, the per capita energy footprint of China was also far higher than the regional average of South Asia (21.5 GJ per capita), but closer to the regional average of East Asia and the Pacific, i.e., 88.1 GJ per capita [43]. India's energy footprint per capita showed a steady increase from around 13.9 GJ/capita in 1990 to about 24.4 GJ/capita in 2018. While the growth was not as rapid as China's, it still indicates a consistent rise in energy consumption as the country continues to develop. Indonesia and Thailand exhibited fluctuations in energy consumption per capita, but with an overall upward trend. Both countries experienced growth in energy consumption, depicting ongoing economic development.

On the other hand, considering the consumption and production perspectives, there was a significant difference in the energy use profile of Indonesia. The energy footprint per capita was much lower than the domestic energy use per capita, indicating that Indonesia is a net exporter in terms of the primary energy. Pakistan's energy footprint per capita remained relatively stable throughout the years, with a moderate increase from around 12.7 GJ/capita in 1990 to about 16.2 GJ/capita in 2018. Vietnam's energy consumption per capita experienced a sharp increase from around 11.4 GJ/capita in 1990 to approximately 35.5 GJ/capita in 2018. This remarkable growth likely reflects the country's economic expansion and industrialization. The data show that energy consumption per capita significantly varied across the countries. China and India, being highly populous countries, have higher energy consumption overall compared to smaller countries such as Vietnam and Thailand. Overall, there seems to be a general trend of increasing energy consumption per capita across these countries, which is in line with the global trend of a growing energy demand driven by economic development.

The progress in energy productivity improvement greatly varied across regions. China is aiming to reduce its energy consumption per unit of GDP by 13.5% between 2021 and 2025, focusing on a considerable increase in energy efficiency [77]. On the other hand, India is focusing on reducing the energy intensity by 45% by 2030, considering 2005 level as the base year [78]. Thailand announced a target for an energy intensity reduction of 30% by 2036 (considering a baseline year of 2010) in the Energy Efficiency Plan 2015–2036 [79].

Further, it was observed that all the countries exhibited a weak or even negative decoupling in the early 1990s. This depicts that their economic growth was closely associated with increased energy consumption—essentially, as the economy grew, so did the energy usage. As time progressed, particularly after 2005, some of these countries began to show signs of improvement in terms of relative decoupling. This can be observed through their positive decoupling values in Figure 7, where the rate of economic growth started to outpace the corresponding increase in energy consumption. Notably, some countries, such as Vietnam, demonstrated a shift from negative decoupling to positive values, indicating a move toward more energy-efficient economic growth over time. China and Indonesia consistently showed a positive trend, specifying an ongoing effort to decouple economic growth from energy use. Similarly, India showed an upward trend, indicating a potential transition toward more sustainable growth patterns. However, the degree of decoupling varied among countries. China's decoupling factor generally steadily increased, while India experienced a somewhat abrupt and slower rate of change. Overall, the data reflect the intricate relationship between economic development and energy consumption. The shift toward positive decoupling factors in certain years and countries is indicative of the efforts, such as technological advancements, policy interventions, and changes in consumption patterns, to achieve relatively more sustainable growth by utilizing energy resources more efficiently.

3.6. Water Use

Water plays a pivotal role in sustaining species and ecosystems, serving as a critical resource. Additionally, it holds indispensable significance in agriculture and a multitude of economic endeavors. Particularly in instances where the demand for water surpasses the local availability, comprehensive water management becomes imperative. This ensures the fulfillment of requisites, prevents water scarcity, and mitigates the impact of droughts. Two distinct SDGs revolve around the responsible utilization of water: SDG 6 and SDG

12, emphasizing the proficient use and integrated governance of freshwater resources, encapsulated within the realm of clean water and sanitation. Meanwhile, SDG 14, dedicated to life below water, is committed to the preservation of marine resources and oceans. These goals acknowledge water as a communal asset necessitating collective attention.

The ratio of economic output (GDP) to the water footprint (WF) is used as the measure of water footprint productivity. China witnessed a substantial surge in its domestic water withdrawal, with a notable rise from 130.8 billion m^3 in 1990 to 222.6 billion m^3 in 2018, as shown in Figure 8. The main reasons for the significant rise in China's domestic water withdrawal are urbanization, agricultural activities, economic growth, and water-intensive industries. China is one of the largest producers of wheat, rice, and maize crops globally, which require significant amounts of irrigation water [80]. China's integration into the global economy, improvement in lifestyle, and GDP per capita have led to the utilization of water resources from various corners of the world. This occurs through the import of products that involve water in their manufacturing processes. The water consumption footprint escalated by 63.1% from 1990 to 2018, reaching a value of 130 to 211.9 billion m^3 from 1990 to 2018. The phenomenon of globalization and expansive global supply chains has led to a growing spatial disconnect between the environmental pressures and impacts stemming from the production and consumption of traded commodities. The ratio of economic output (GDP) to the domestic water withdrawal is used as the measure of production-based domestic water withdrawal productivity. Domestic water withdrawal productivity in China increased almost 8-fold from 1990 to 2018. In 1990, the consumption-based water productivity of China was USD 6.3 per cubic meter, which increased to USD 51.3 per cubic meter in 2018. Overall, the increase in water productivity is mainly due to the enhanced efficiency of water use in the agricultural sector in China. The agriculture water use efficiency increased from 0.68 to 0.75 from 2000 to 2020 [81]. The domestic water withdrawal per capita of China has increased by 38%, increasing from 115 to 160 m^3/capita from 1990 to 2018, whereas the water footprint per capita of China has increased by 33%.

In Figure 8, the progression of domestic water consumption in India over the period from 1990 to 2018 is marked by a notable increase of almost 50%, ascending from 211.5 billion m^3 to 315.9 billion m^3. Within this context, a detailed breakdown of water usage reveals that the predominant sector in terms of domestic water withdrawal is agriculture, accounting for a substantial share of 295.8 billion m^3, whereas non-agricultural water consumption follows, with a comparatively lesser quantity of 20.1 billion m^3 [43]. The reasons for the increase in domestic water withdrawal in India are probably due to the increase in agricultural land expansion, which required more irrigation water. This upward trajectory in water utilization is reflected by a 44.3% expansion in India's water footprint throughout the same timeframe. The prime contributor to this footprint is the agricultural domain. Additionally, a significant enhancement in domestic water withdrawal productivity was observed, with productivity more than tripling, from USD 2.4 per cubic meter of water in 1990 to USD 8.9 per cubic meter of water in 2018. The increase in the water productivity in India is mainly due to the increase in the agricultural area under high-efficiency irrigation systems [82]. This growth is mirrored in the improvement of the water footprint productivity, which experienced an almost 4-fold surge, progressing from USD 2.4 to 9.3 per cubic meter of water. In parallel, the volume of India's domestic water intake underwent a notable increase of 38%, rising from 115 m^3 per capita in 1990 to 160 m^3 per capita in 2018. However, in terms of individual water usage, a modest declining trend of 7% was discerned between 1990 and 2018.

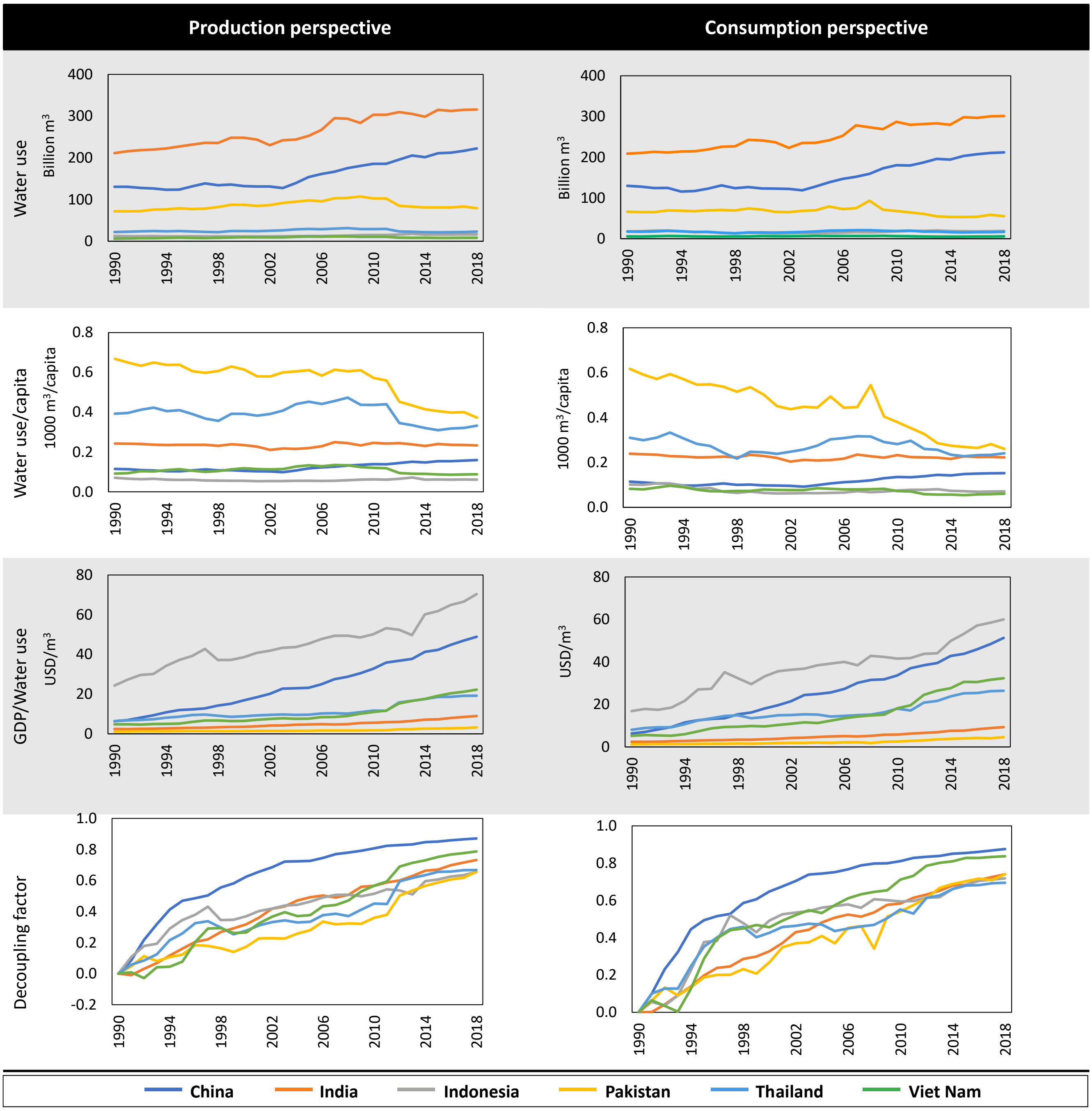

Figure 8. Total water use, water use per capita, and water productivity considering the consumption and production perspectives.

The increase of domestic water consumption in Indonesia between 1990 and 2018 showed a substantial increase of 27.9%, transitioning from 12.8 billion m^3 to 16.3 billion m^3. This growth pattern was seen in the distribution of water usage sectors in 2018, where agricultural water consumption dominates with a significant portion of 16.1 billion m^3, followed by non-agricultural water consumption constituting a mere 0.2 billion m^3. The overarching water consumption footprint of Indonesia presented a 4.1% expansion over the examined timeframe, reaching 19.1 billion m^3 in 2018. In alignment with the sector-specific consumption, the agricultural domain retained the major share in the water consumption footprint, accounting for 18.1 billion m^3, while non-agricultural water usage contributed 1.1 billion m^3 to the footprint. The trajectory of domestic water withdrawal productivity in

Indonesia revealed an impressive tripling effect from 1990 to 2018. Commencing at USD 24.3 per cubic meter of water in 1990, the water productivity notably escalated to USD 70.3 per cubic meter of water in 2018. Similarly, the enhancement in the water footprint productivity was stark, exhibiting a 3-fold increase from USD 17 to 60 per cubic meter of water. On a per capita basis, Indonesia's domestic water withdrawal experienced a moderate decline of 10%, transitioning from 70 m^3 per capita in 1990 to 60 m^3 per capita in 2018. A more substantial reduction was evident in the water footprint per capita, which diminished by 29% over the three-decade period, descending from 101 m^3 per capita in 1990 to 71 m^3 per capita in 2018.

From 1990 to 2018, domestic water consumption in Pakistan increased by 10.1%, from 71.9 billion m^3 in 1990 to 79.1 billion m^3 in 2018. In 2018, agriculture water consumption had the largest share in water consumption at 78.3 billion m^3, followed by non-agriculture water consumption at 0.8 billion m^3. Due to globalization and global supply chains, Pakistan is reliant on water resources in almost all countries around the world via imports of goods where water was used in the production process. The domestic water withdrawal productivity in Pakistan has increased almost three times from 1990 to 2018. In 1990, the water productivity was USD 24.3 per cubic meter of water, which increased to USD 70.3 per cubic meter of water in 2018. In the same way, the water footprint productivity also increased by more than three times, increasing from USD 17 to 60 per cubic meter of water. The domestic water withdrawal per capita and the water footprint of Pakistan are the highest as compared to the other countries under consideration. However, both indicators showed a sharp decline in trends in the last three decades due to a massive increase in the population and the exported products having higher water footprint values. The domestic water withdrawal per capita of Pakistan decreased by 44%, from 667 to 373 m^3/capita from 1990 to 2018. The water footprint per capita of Pakistan also decreased by 58%, from 617 to 260 m^3/capita from 1990 to 2018.

The domestic water consumption in Thailand increased by 3.9%, from 22.2 billion m^3 in 1990 to 23.1 billion m^3 in 2018. In 2018, agriculture water consumption had the largest share in water consumption, at 22.4 billion m^3, followed by non-agriculture water consumption (0.7 billion m^3). The water consumption footprint of Thailand decreased by 4.7% from 1990 to 2018. It accounted for 16.7 billion m^3 in 2018. Agriculture water consumption had the largest share in the water consumption footprint in 2018, at 15.7 billion m^3, followed by non-agriculture water consumption at 1.1 billion m^3. The domestic water extraction productivity of Thailand increased about three times from 1990 to 2018. The water productivity grew from USD 6.4 per cubic meter of water in 1990 to USD 19.2 per cubic meter of water in 2018. Figure 8 shows that the water footprint productivity increased by more than three times. The productivity of domestic water extraction in Thailand experienced a 3-fold increase between 1990 and 2018. Water productivity surged from USD 6.4 per cubic meter in 1990 to USD 19.2 per cubic meter in 2018. This growth is akin to the ascent observed in the water footprint productivity, which escalated from USD 8.1 to 26.5 per cubic meter of water. Figure 8 vividly illustrates that the productivity of the water footprint also expanded by over 3-fold.

From 1990 to 2018, domestic water consumption in Vietnam increased by 35.9%, from 6.2 billion m^3 in 1990 to 8.4 billion m^3 in 2018. In 2018, agriculture water consumption had the largest share in water consumption, at 6.5 billion m^3, followed by non-agriculture water consumption at 1.9 billion m^3. The water consumption footprint of Vietnam increased by 3.4% from 1990 to 2018. It accounted for 5.8 billion m^3 in 2018. The domestic water withdrawal productivity of Vietnam increased slightly less than five times from 1990 to 2018. In 1990, the water productivity was USD 4.7 per cubic meter of water, which increased to USD 22.2 per cubic meter of water in 2018. Similarly, the water footprint productivity also increased by more than six times, from USD 5.3 to 32.3 per cubic meter of water. The domestic water withdrawal per capita of Vietnam decreased by 15%, from 392 to 332 m^3/capita from 1990 to 2018. The water footprint per capita of Thailand showed a slight decrease in the trends, from 91 to 88 m^3/capita from 1990 to 2018. Overall, the change is insufficient.

4. Conclusions

The analysis presented in this study underscores the intricate interplay indicators related to the triple planetary crisis (GHG emissions, pollutant emissions, and biodiversity loss) and resource use (material use, energy use, and water use), and their profound impacts on the environment, society, and economy. The comprehensive assessment of these resource utilization patterns across six countries—China, India, Indonesia, Pakistan, Thailand, and Vietnam—provides a deep understanding of their trajectories and the potential implications for sustainability and biodiversity conservation.

The study highlighted the critical importance of addressing the triple planetary crises—biodiversity loss, pollutant emissions, and climate change—in a holistic manner. Efforts by six Asian countries (China, India, Indonesia, Pakistan, Thailand, Vietnam) to mitigate climate change were comprehensively discussed. China's GHG emissions surged tremendously over the past three decades. On the other hand, the government is committed to achieve carbon neutrality by 2060. India achieved partial decoupling of emissions from economic growth, focusing on renewable energy. Vulnerable Pakistan seeks emission reductions and finance, while Indonesia aims to cut emissions through sustainable practices. Thailand and Vietnam have also outlined emission reductions and strategies. Land use change emerged as a significant driver of biodiversity loss, underscoring the urgency of adopting sustainable land use policies, enhancing conservation efforts, and embracing eco-friendly practices. The analysis of material use shed light on the complexities of resource consumption, showcasing the need for optimizing production methods, promoting circular economies, and adopting innovative technologies to minimize waste and environmental impacts. Energy use is a central pillar of economic development, but the analysis emphasized the necessity of decoupling economic growth from energy consumption to mitigate environmental burdens. This can be achieved through increased energy efficiency, investments in renewable sources, and the pursuit of cleaner and sustainable energy pathways. Water, a finite resource crucial for life and various economic activities, demands prudent management to prevent scarcity and ecosystem degradation. This study underscores the significance of improving water productivity, both in terms of domestic water withdrawal and the water footprint, to ensure responsible usage and reduce environmental stresses. Additionally, we highlighted the need for international collaboration and policy reforms to address the complexities of water consumption embedded in global supply chains. Further, while comparing the production and consumption sides of all the considered indicators, interesting trade dynamics can also be observed among the considered countries. The analysis of decoupling trends between economic growth and resource use and environmental impacts across the observed countries revealed a complex pattern. The initial years showed a close connection between economic expansion and increased resource use, as well as the environmental impacts. However, a shift toward relative decoupling became apparent after 2000, as some countries demonstrated positive decoupling values, indicating economic growth outpacing consumption growth and the environmental impacts. On the other hand, the absolute decoupling of economic growth from resource use along with the environmental impacts still seems unrealistic as economic growth is very much dependent on resource use.

Conclusively, the adaptation of holistic approaches, such as technological innovations, sustainable practices, and public awareness campaigns, are recommended. These measures are pivotal in achieving a harmonious balance between economic development, resource utilization, and environmental conservation. The insights provided by this analysis serve as a roadmap for policymakers, researchers, and stakeholders to navigate the challenges of sustainable development and strive toward a more resilient and equitable future. Further, supporting innovation and public awareness campaigns can foster a more resilient and equitable future. This study has provided a valuable analysis, focusing on six countries in Asia, although the findings may not be fully generalizable to the whole region. Additionally, we relied on available data that were based on several databases, which may have limitations in terms of comprehensiveness. The relative decoupling trends observed, while informative, may not capture all the complexities associated with resource use and environmental impacts. Future research could benefit from a more extensive dataset and a broader geographical scope to enhance the robustness of the conclusions. Despite these limitations, this study still offers a valuable foundation for understanding the challenges and opportunities associated with resource use for sustainable consumption and production in the selected countries.

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