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Sustainability Assessment of the Upstream Bengawan Solo Watershed in Wonogiri Regency, Central Java Province, Indonesia

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Abstract: The sustainability of watershed management is a key issue that must be considered to ensure the continuation of watershed services such as agriculture, food, and energy. This concern has also been raised in Presidential Regulation No. 2/2015 and No. 18/2020 regarding the National Medium-Term Development plans for the periods of 2015–2019 and 2020–2024, which mandate the restoration of priority watersheds, one of which is the Upstream Bengawan Solo Watershed. The purpose of this study is to fill this knowledge gap by measuring the sustainability of this watershed from a time dynamics perspective. However, several factors can influence the achievement of sustainable development. This paper assesses the sustainability of the watershed over several periods using MDS (Multidimensional Scaling) analysis with the assistance of modified Rapfish (Rapid Appraisal for Fisheries) software (2013 version). The information used in this case study was collected from 20 districts in relation to social, economic, and environmental dimensions. Our result shows that the average index of the social dimension increases from 2007 to 2019 and 2021, while the economic dimension tends to fluctuate. A decrease occurs from 2007 to 2019, and then increases from 2019 to 2021. This differs significantly from the environmental dimension, which decreases from 2007 to 2019 to 2021. The sustainability scores were then compared across regions. The lessons learned in this study can be incorporated into regional policies and actions to overcome challenges in the implementation phase.

Keywords: sustainability assessment; watershed; Rapfish; spatiotemporal

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1. Introduction

The Bengawan Solo Watershed is the longest and widest river on Java Island, Indonesia, with an area comprising ±12% of the total area of the island. As part of Bengawan Solo, the Wonogiri Multipurpose Reservoir (WMR), located in Wonogiri Regency, Central Java Province, is an artificial lake/reservoir that dams the river. Some of the main functions of reservoirs include: (1) controlling floods; (2) irrigation (the Bengawan Solo irrigates more than 23,600 hectares of agricultural land in the Regencies of Sukoharjo, Klaten, Karanganyar, and Sragen); (3) supplying raw water (the Bengawan Solo supplies water to the Local Water Company (PDAM)) and industrial water; (4) generating hydroelectric power (the Bengawan Solo generates 12.4 Megawatts; (5) tourism; and (6) inland fisheries [1]. WMR has been operating since 1978 and has experienced siltation and a reduced capacity due to sedimentation. In 1993–2005, the average annual sediment inflow into the Wonogiri reservoir reached 3.2 million m^3/year [1,2]. Due to land conversion, sediment transport through surface flows causes reservoir shallowing [3].

Watershed problems cannot be addressed from just one dimension at a time but must be viewed from multiple dimensions, namely economic, social, and environmental, over several periods [4–7], in the context of riparian ecosystems [8–10] and sustainability [11]. Reduced water quality and quantity has become a critical limitation in watershed development around the world [12]. Therefore, a primary objective of watershed management is to find solutions to mitigate this problem [13]. Stakeholder participation is needed to produce an integrated catchment management plan that includes the restoration of water quality and quantity. Decision-makers need adequate technical support, because good decision-making depends on ex ante evaluation, continuous monitoring, and ex post evaluation.

Based on the above, the following question arises: Were there any changes in sustainability since the reservoir began operating in 1978? Measuring sustainability at this level is still a challenge [14]. First, sustainable development indicators have been extensively discussed at global, national, and regional levels, but they are still constrained at the local level. However, at the local level, there is spatial interdependency between locations. So, the sustainability performance of a location is affected by the conditions in its surrounding areas [15]. Second, the process of preparing sustainability indicators is complex. Third, sustainability measurement methods are complicated. Finally, there is a lack of resource capacity and data availability at the regional level.

Given these limitations, it is essential to create a straightforward approach that is easy to use and apply in order to evaluate sustainability. This paper improves upon previous studies on watershed sustainability measurements conducted by Widicahyono (2020) [16], Murdiyanto (2016) [17], Hamzah (2016) [18], and Syamsiyah (2023) [19], which were limited to one period. The primary goal of this paper is to evaluate watershed sustainability over multiple timescales, which can further assist in making more fundamental spatial planning policy decisions in the future. We use MDS (Multidimensional Scaling) analysis and a modified Rapfish (Rapid Appraisal for Fisheries) method that is easy to use and apply in order to quickly evaluate the sustainability status of water resource management (rapid appraisal) in several periods [4–7].

2. Literature Review

In this section, we present a literature review in order to establish a strong theoretical basis for addressing the research problem, and also to compare the present research against existing studies from other countries so that gaps in knowledge can be identified (Table 1).

Table 1. References of Watershed Sustainability.

No	Reference	Country	Method
1	Kim 2021 [13]	Korea	Multivariate log-linear model
2	Razo 2023 [20]	Mexico	Watershed sustainability index (WSI)
3	Geng 2022 [21]	China	Spatial autocorrelation method
4	Li 2023 [22]	China	Linear regression and GIS analysis with a Loess Plateau area coverage of 773.5 km^2
5	Liang 2023 [23]	China	Partial least squares method on the Pearl River Basin
6	Lu 2021 [24]	China	Interval fuzzy two-stage stochastic model

2.1. Sustainability

The concept of three pillars of sustainability, consisting of social, economic, and environmental, was first proposed by Barbier (1987) [25]. Historically, there is no single origin for this three-pillar concept. Still, it has gradually developed, with various criticisms presented in the academic literature, in an effort to align economic growth as a solution to social and ecological problems [26]. In the development of this concept, these three pillars have been found in various forms, including in academic literature, in policy documentation, in business literature, and online. Reinforcing their importance, the three pillars have been embedded within the SDGs initiated by the UN [27].

The International Union for the Conservation of Nature is credited with first popularizing the term "sustainable development" (IUCN, 1980), better known as the Brundtland Report, in 1987, which defined sustainable development as development that meets current needs without compromising the ability of future generations to do so in order to meet their own needs [28,29]. Although the importance of preserving resources has been acknowledged since the 1800s [30], the basic principles of sustainable development, which aim to address economic development while considering the environment, were established in an international forum through the United Nations Conference on the Human Environment [31], which produced the UN Environment Program and the Stockholm Declaration. During the same time frame, Meadows et al.'s research in 1972 [32] marked the first attempt to model how economic development affects resource depletion and the quality of soil and water, which are currently regarded as crucial factors in sustainable development.

Economic sustainability refers to the processing of natural resources while considering nature, society, and humans in the context of the equal distribution of prosperity. Economic sustainability relates to production processes that meet current consumption levels without sacrificing future needs [33].

Social sustainability encompasses the ideas of equality of utility, empowerment, accessibility, participation, and institutional stability to preserve the environment. Several social researchers have identified a close relationship between social conditions (poverty) and environmental damage, where poverty leads to the need to exploit resources without considering the impact of environmental damage [34].

Environmental sustainability includes ecosystems, environmental carrying capacity, and biodiversity, and states that natural capital needs to be maintained as economic input and a waste absorber so that it cannot be used up before the residue can be assimilated back into nature. Goodland (in text) argues that one must expect to "live within limitations" [35–41].

Achieving economic, social, and environmental sustainability must occur alongside and not at the expense of other initiatives. Likewise, without attaining social and economic sustainability goals, environmental sustainability cannot be achieved. Poverty alleviation and sustainable economic growth are essential elements of environmental sustainability, and vice versa.

2.2. Sustainability Assessment

Sustainability is a multidimensional concept with economic, social, and environmental aspects that must be considered and integrated [42,43], so an instrument is needed that can measure sustainability by selecting appropriate indicators, which forms part of the methodology of [44,45].

Agenda 21 was adopted during the United Nations Conference on Environment and Development in Rio de Janeiro in 1992, which discussed measuring sustainable development and developing indicators for its assessment for the first time. Agenda 21 called for the creation of a system for tracking and assessing progress toward achieving sustainable development through the adoption of indicators that track changes in the social, economic, and environmental spheres [41,46].

Of the various indexes that have been proposed, none of which are universally accepted by the scientific and political communities as the preferred one, all attempt to rank nations according to their accomplishments across a variety of indexes [47–54].

Sustainability assessments can be developed using a variety of approaches, depending on the objectives, scale, and scope of the study [55]. As a result, the literature on this topic is growing, offering various approaches [56]. Some examples of sustainability assessment models can be found in studies by Boggia and Cortina (2010) [57], who developed a methodological approach based on multicriteria analysis to assess sustainability in specific fields; Kropp and Lein (2012) [58] and Lombardi and Ferretti (2015) [59], who produced aggregate sustainability indexes; and Lopez and Monzon (2010) [60], who proposed the MCDSS, which works with three different indexes.

The sustainability index is a method used to measure the sustainability progress achieved by a region so that the result can then be transmitted to the community and decision-makers. In Razo's research conducted in 2023, sustainable development in the Santiago–Guadalajara River Basin (SGRB), which passes through Guadalajara, Mexico's second most populous city, is assessed using the watershed sustainability index (WSI). The research results show that the SGRB has a low level of sustainability characterized by alterations in land use that lead to environmental degradation; this is strengthened by the fact that over the last 50 years, there has been an increase in the population. As the country's most contaminated canal, the SGRB was created through the rapid development of agriculture and industry. Other factors that have contributed to environmental degradation include insufficient municipal solid waste management, inadequate wastewater treatment, and the extensive use of agricultural pesticides. Additionally, this study discovered that while sustainability is at a medium level in the central region due to adequate water resources, it is poor in the upstream and downstream portions of the river basin due to environmental deterioration brought on by changes in land use. The study's conclusions can be used to educate interested parties about the state of the SGRB and the need for action to promote its recovery and sustainability [20].

Research conducted by Geng et al., 2022 [21] explores the use of remote sensing to monitor the urban ecological environment and investigate the key variables influencing its changes, together with the negative ecological effects and environmental issues brought about by rapid urbanization. Their study uses the remote sensing ecological index (RSEI) to quantify the ecological quality of the region from 2000 to 2020. Geodetector and geographically weighted regression are used to analyze the data. According to the findings, there is autocorrelation and an increase in Fuzhou City's RSEI, followed by a decline, between 2000 and 2020. The main driving factors causing RSEI spatial divergence are height, slope, and GRDP, and each factor's driving influence and range changes over time.

In Indonesia, sustainability analysis with Rapfish was first conducted by the authors of [61] in an analysis of fisheries' sustainability in Jakarta Bay. Even though Rapfish was designed for sustainability analysis in the fisheries sector, the analysis of sustainability development can be applied to other sectors by understanding the analysis requirements in those contexts [62]. Previous research in Indonesia has also used the Rapfish method to identify the sustainability index or status in various fields [63–69].

The Rapfish (Rapid Appraisal for Fisheries) software, created by the Rapfish Group Fisheries Center at the University of British Columbia in Canada, will be used in this paper to calculate the sustainability index [70].

2.3. Watershed Management

River basins are natural landscapes that receive and accommodate rainwater, groundwater, and surface water and channel it to lower areas of rivers, tributary reservoirs, and other water bodies. A watershed is analogous to a water catchment area limited by topography that holds and drains water [71–79].

River basins are providers of ecosystem services needed by humans, such as supporting services for soil formation, food and water, wood, fiber, flood control, climate adjustment, water filtration, and cultural services like leisure.

Water resources in many regions are considered commodities that can be exploited by humans until they exceed the limits of their carrying capacity. Due to this, coupled with the acceleration of the rate of land use change upstream and the impact of global climate change, the quality and quantity of watershed services is decreasing rapidly [21,24,80–83].

Plant roots can absorb water that falls to the soil's surface, and then, bind it into a groundwater supply in the top layer of soil. Meanwhile, land converted into open/built-up land will produce more significant water runoff [84–87]. Runoff is an essential component in watershed management, especially soil conservation, where the runoff value represents the regulation of the relationship between rainfall intensity and runoff, as well as the regulation of surface flow. A large amount of runoff indicates that the rainwater that falls is not absorbed into the ground but directly becomes surface flow. The magnitude of the surface flow coefficient indicates the physical condition of a watershed, where the greater the value of the flow coefficient, the greater the amount of rainwater that becomes runoff water, and thus, the less water becomes groundwater storage. The greater this value, the more severe the damage to a watershed, causing flood disasters.

In addition to serving as raindrop buffers, preventing particle disaggregation, and lowering sediment loads, crops can minimize the direct effects of rainfall [88,89]. Because well-managed grasslands avoid erosion and preserve the physical, chemical, and biological qualities of the soil, they can be regarded as sustainable. Vegetation-covered areas (including thatch) generally show reduced soil loss, demonstrating the significance of vegetation cover in preventing soil degradation.

In addition to vegetation cover, other factors that affect water infiltration into the soil include texture, porosity, soil density, rainfall, and compaction level. Land processing activities using tractors, hoes, and harvesting, which break up soil layers, should be reduced and replaced with the planting of crops after harvest, such as corn and soybeans, to minimize soil loss, which results in erosion [90–92].

Based on research conducted by Geng et al., 2022 [21], erosion is not caused by soil texture or its location in upstream, middle, or downstream areas; it is more closely related to land processing, where a system that involves fewer plants and more soil scarification will result in more significant soil loss. To lower soil erosion and boost sustainability, producers of agricultural products must cultivate crops year-round and, in comparison to covered soil, limit soil disturbance.

In order to restore ecology, Li et al., 2023 [22] examined the traits and origins of runoff variations. This study investigates the features of surface evolution and underlying meteorological changes using a number of statistical techniques. The results show that human activities have a more significant impact than climate change on reducing water runoff. Thus, human efforts in the future will significantly influence environmental sustainability.

Key elements influencing regional water quality include variations in spatial characteristics and land use patterns, where poor conditions occur upstream and good conditions occur in the middle of the watershed. In [23], a regression model explains the quantitative relationship between land use, landscape patterns, and water quality, and it is concluded that urban land has the biggest impact on water quality.

To assess the attainment of water quality and determine the factors influencing it, such as flow and season, a study used a multivariate log-linear model. The study's outcomes were statistically significant and suitable for forecasting BOD and TP concentrations [13].

Many environmental issues, including river and tributary pollution, chemical product transportation, sedimentation-causing particle deposition, exposure to carbon deposits, surface layer removal, road damage, flooding, dam breaks, and harm to local biodiversity, are caused by the loss of land and water in upstream watersheds [88]. There is a need for natural conservation methods, such as vegetation management programs, and engineering methods, such as terracing, improving soil reinforcement in water catchment areas, improving drainage channels, and building dams.

Since watersheds are social–ecological and hierarchical systems with many levels of management organization, comprehensive and multidisciplinary management is required [89,93].

There are conservation policies in other countries that have succeeded in dealing with problems in watersheds. For example, in Brazil, environmental conservation policies have contributed to reducing soil and water loss, namely farming without tillage, restoring degraded springs, carbon sequestration, and implementing low-carbon agroforestry systems, the protection of protected areas (protected forests, nature reserves), and the management of natural resources with the following aims: (1) guaranteeing that the water required for current and future generations is available and meets the necessary quality standards for use; (2) using water resources in a logical and integrated manner; (3) preventing the development of critical hydrological criticalities, whether they are caused by improper use or natural causes, in order to promote and enhance the collection, conservation, and utilization of rainfall. In addition to reducing soil loss, this initiative helps to maintain biodiversity within biomes, raise carbon stocks, and prevent rivers and lakes from becoming shallower due to continuous erosion processes [84].

To preserve pedological and edaphic resources as quickly as possible, land cover and minimal disturbance are prerequisites. An alternate approach that can be discontinued in this instance is the proper management of soybean plants using a direct planting system and contour planting [88].

This research examines the ways in which sustainable land use can be effectively supported by land use allocation. Models are used in a lot of research, including mathematical and geographical analytic models to solve land use planning issues. These models, however, do not consider all three of the factors that contribute to uncertainty in land use systems. Thus, taking into account regional land–society–economic–environmental systems under uncertain conditions, this study creates a model for allocating land usage. In order to provide a sustainable development strategy, this model combines fuzzy interval social, economic, and ecological factors with a two-stage random land use allocation model. The results show that the model can accurately represent the quantitative relationship between increasing economic advantages and ecological and social issues [24].

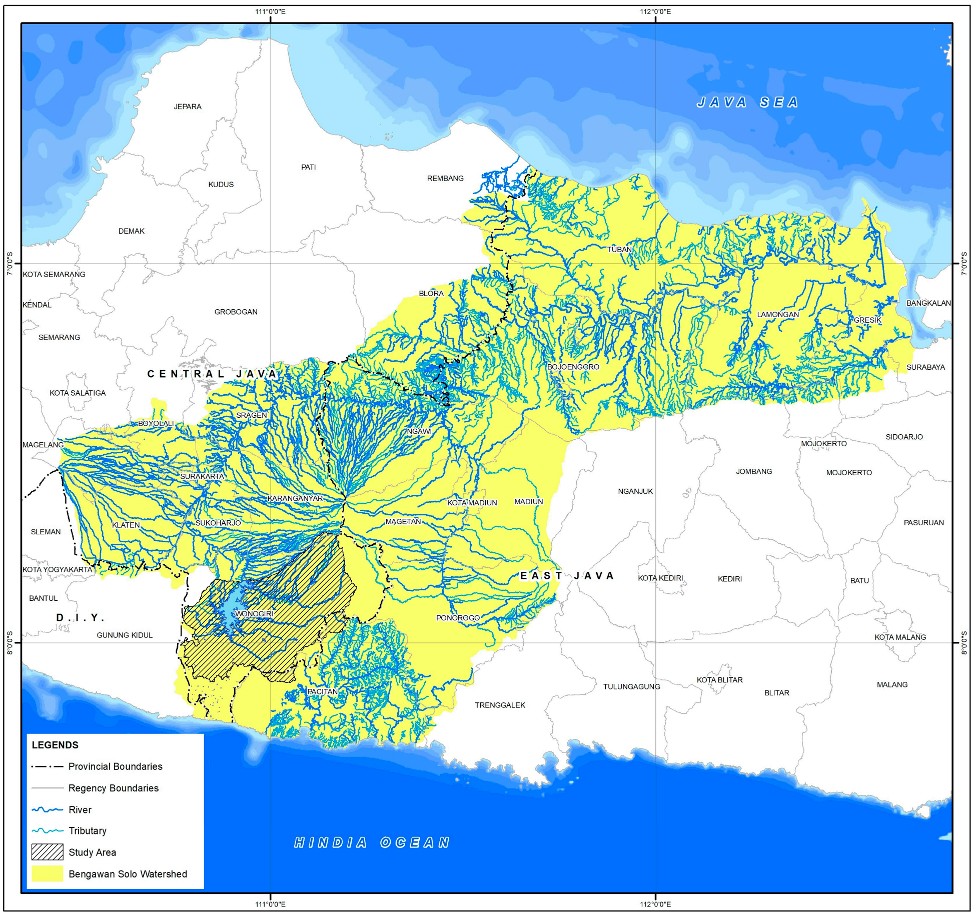
3. Materials and Methods

3.1. Study Area

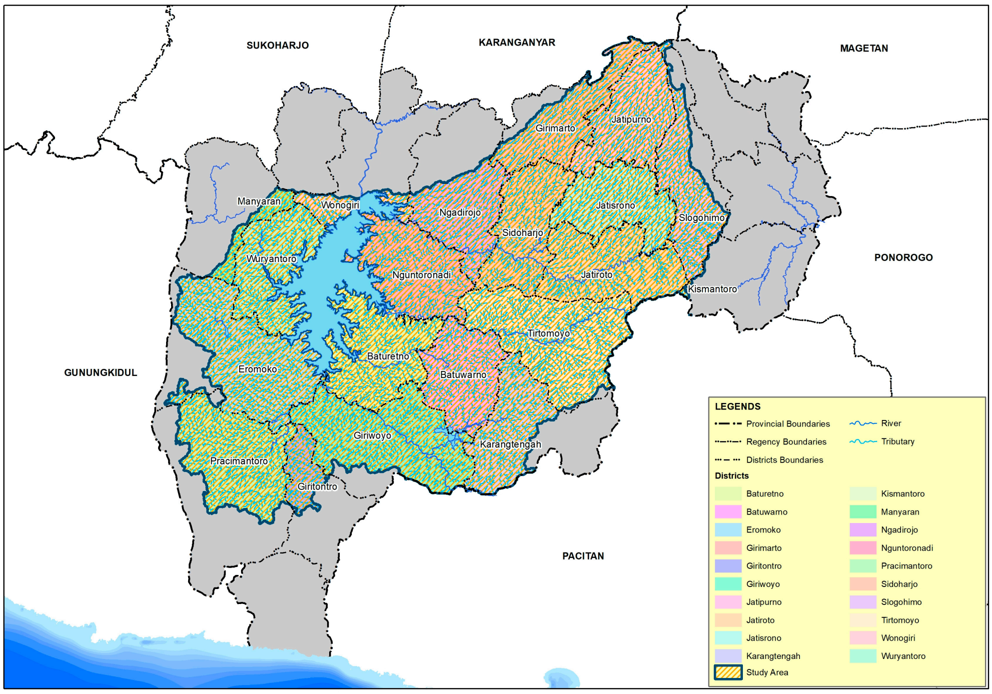
The study area is located in the Upstream Bengawan Solo Watershed, Bengawan Solo River Basin, which represents a water catchment area for the WMR. The study area is 136.931 hectares and administratively consists of 20 districts that form part of Wonogiri Regency, Central Java Province, Indonesia (Figure 1).

(**a**)

Figure 1. *Cont.*



(**b**)



(**c**)

Figure 1. (**a**) Map of the Bengawan Solo Watershed area oriented towards Indonesia; (**b**) map of the Upper Bengawan Solo Watershed oriented towards the Bengawan Solo Watershed; (**c**) study area map.

3.2. Data Collection Methods

Data collection was carried out through literature studies from various sources in the central government, such as the Ministry of Environment and Forestry, the Ministry of Agrarian Affairs and Spatial Planning/National Land Agency, and the Ministry of Public Works and Public Housing, as well as regional governments, such as the Regional Planning Agency, the Environmental Agency, the Department of Public Works and Public Housing, and the Central Bureau of Statistics and State-Owned Enterprises.

Data were obtained from the Central Bureau of Statistics in the form of Village Potential Documents, each of which consists of several time series (temporal), namely 2007, 1999, and 2021. The data include social, economic, and environmental information for 20 districts. The social dimension is constructed of 10 variables related to health, population, the use of government land, and the use of social facilities. The economic dimension includes 9 variables related to human economic activities such as industry, agriculture, tourism, transportation, and mining, along with the condition of facilities and utilization of irrigation infrastructure. Meanwhile, the environmental dimension includes variables such as forestry, disasters, water quality, the availability of water resources, and the condition of agricultural land. Details of the variables and sub-variables for each dimension are given in Table 2.

Table 2. List of variables.

Code	Themes	Variables	Sub-Variables	Bad	Good	Description	References
Social Dimension							
VSOC1	drinking water	number of households served by sustainable safe drinking water	percentage of households in each district served by Local Water Company (PDAM)	1	10	10 = ≥76.5; 9 = ≥68 and <76.5; 8 = ≥59.5 and <68; 7 = ≥51 and <59.5; 6 = ≥42.5and <51; 5 = ≥34 and <43.5; 4 = ≥25.5 and <34; 3 = ≥17 and <25.5; 2 = ≥8.5 and <17; 1 = <8.5	[29,57,94–103]
VSOC2	sanitation	number of villages whose residents have access to sanitation facilities	percentage of villages in each district whose households have toilets	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[29,57,94–99,101,102]
VSOC3	health facilities	number of health facilities	number of health facilities with weight (health center weight = 30 and hospital weight = 70)	1	10	10 = ≥279; 9 = ≥248 and <279; 8 = ≥217 and <248; 7 = ≥186 and <217; 6 = ≥155 and <186; 5 = ≥124 and <155; 4 = ≥93 and <124; 3 = ≥62 and <93; 2 = ≥31 and <62; 1 = <31	[94,95,97,102–104]
VSOC4	density	population density	population density	1	10	1 = ≥9.36; 2 = ≥8.32 and <9.36; 3 = ≥7.28 and <8.32; 4 = ≥6.24 and <7.28; 5 = ≥5.20 and <6.24; 6 = ≥4.16 and <5.20; 7 = ≥3.12 and <4.16; 8 = ≥2.08 and <3.12; 9 = ≥1.04 and <2.08; 10 = <1.04	[95,102,103]
VSOC5	sanitation	number of villages whose residents discard rubbish in the river	percentage of villages in each district that throw rubbish into the river	1	10	1 = ≥18; 2 = ≥16 and <18; 3 = ≥14 and <16; 4 = ≥12 and <14; 5 = ≥10 and <12; 6 = ≥8 and <10; 7 = ≥6 and <8; 8 = ≥4 and <6; 9 = ≥2 and <4; 10 = <2	[29,57,94–97,99,101–103]
VSOC6	sanitation	number of villages whose residents use the river for bathing and washing	percentage of villages in each district that use the river for washing and bathing	1	10	1 = ≥72; 2 = ≥64 and <72; 3 = ≥56 and <64; 4 = ≥48 and <56; 5 = ≥40 and <48; 6 = ≥32 and <40; 7 = ≥24 and <32; 8 = ≥16 and <24; 9 = ≥8 and <16; 10 = <8	[94,96,97,102,103]
VSOC7	settlement pattern	number of households residing on the riverbanks	number of households residing on the riverbanks	1	10	1 = ≥72; 2 = ≥64 and <72; 3 = ≥56 and <64; 4 = ≥48 and <56; 5 = ≥40 and <48; 6 = ≥32 and <40; 7 = ≥24 and <32; 8 = ≥16 and <24; 9 = ≥8 and <16; 10 = <8	[94–97,101–104]

Table 2. *Cont.*

Code	Themes	Variables	Sub-Variables	Bad	Good	Description	References
VSOC8	organization	number of villages where residents exhibit mutual cooperation	percentage of villages in each district where residents exhibit mutual cooperation	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[29,96,97,102,103]
VSOC9	cooperative	number of villages that have cooperatives	number of villages that have cooperatives	1	10	10 = ≥465; 9 = ≥430 and <465; 8 = ≥395 and <430; 7 = ≥360 and <395; 6 = ≥325 and <360; 5 = ≥290 and <325; 4 = ≥255 and <290; 3 = ≥220 and <255; 2 = ≥185 and <220; 1 = <185	[29,95–97,102,103]
VSOC10	energy use	number of households served by the State Electricity Company (PLN)	number of households served by the State Electricity Company (PLN)	1	10	10 = ≥22.698; 9 = ≥20.176 and <22.698; 8 = ≥17.654 and <20.176; 7 = ≥15.132 and <17.654; 6 = ≥12.610 and <15.132; 5 = ≥10.088 and <12.610; 4 = ≥7.566 and <10.088; 3 = ≥5.044 and <7.566; 2 = ≥2.522 and <5.044; 1 = <2.522	[29,57,94,95,97–99,101–103]
Economic Dimension							
VECON1	economic activities	number of small–medium industries	number of small–medium industries	1	10	10 = ≥1404; 9 = ≥1248 and <1404; 8 = ≥1092 and <1248; 7 = ≥936 and <1092; 6 = ≥780 and <936; 5 = ≥624 and <780; 4 = ≥468 and <624; 3 = ≥312 and <468; 2 = ≥156 and <312; 1 = <156	[29,57,94–105]
VECON2	economic activities	number of economic facilities	number of economic facilities	1	10	10 = ≥63; 9 = ≥56 and <63; 8 = ≥49 and <56; 7 = ≥42 and <49; 6 = ≥35 and <42; 5 = ≥28 and <35; 4 = ≥21 and <28; 3 = ≥14 and <21; 2 = ≥7 and <14; 1 = <7	[94,96,97,101,103–105]
VECON3	economic performance	number of villages where the main source of income is agriculture	percentage of villages in each district where the main source of income is agriculture	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[57,94–97,99,101,103–105]
VECON4	economic performance	number of villages where the main commodity or sub-sector is agriculture (paddy)	percentage of villages in each district where the main commodity or sub-sector is agriculture (paddy)	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[94,96,97,103–105]
VECON5	water resource usage	number of villages whose inhabitants use the river for irrigation of agricultural land	percentage of villages in each district whose inhabitants use the river for irrigation of agricultural land	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[29,102,103]
VECON6	water resource usage	number of villages whose inhabitants use the river for commercial purposes (tourism and industry)	percentage of villages in each district whose inhabitants use the river for commercial purposes (tourism and industry)	1	10	10 = ≥36; 9 = ≥32 and <36; 8 = ≥28 and <32; 7 = ≥24 and <28; 6 = ≥20 and <24; 5 = ≥16 and <20; 4 = ≥12 and <16; 3 = ≥8 and <12; 2 = ≥4 and <8; 1 = <4	[29,97,102,103]
VECON7	water resource usage	number of villages whose inhabitants use the river for transportation	percentage of villages in each district whose inhabitants use the river for transportation	1	10	10 = ≥9; 9 = ≥8 and <9; 8 = ≥7 and <8; 7 = ≥6 and <7; 6 = ≥5 and <6; 5 = ≥4 and <5; 4 = ≥3 and <4; 3 = ≥2 and <3; 2 = ≥1 and <2; 1 = <1	[29,97,102,103]

Table 2. *Cont.*

Code	Themes	Variables	Sub-Variables	Bad	Good	Description	References
VEC0N8	economic activities	distance to economic facilities	distance to economic facilities in kilometers	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[94,96,97,101,103–105]
VEC0N9	mining	number of villages that have group C mining sites	percentage of villages in each district that have group C mining sites	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[95,98,100]
Environmental Dimension							
VENV1	degradation	converted forest area	comparison of forest land use area and forest area based on Ministerial Decree	1	10	10 = ≥18; 9 = ≥16 and <18; 8 = ≥14 and <16; 7 = ≥12 and <14; 6 = ≥10 and <12; 5 = ≥8 and <10; 4 = ≥ 6 and <8; 3 = ≥4 and <6; 2 = ≥2 and <4; 1 = <2	[29,95–98,102–105]
VENV2	number of disaster events	number of landslide events	number of landslide events each year	1	10	1 = ≥18; 2 = ≥16 and <18; 3 = ≥14 and <16; 4 = ≥12 and <14; 5 = ≥10 and <12; 6 = ≥8 and <10; 7 = ≥ 6 and <8; 8 = ≥4 and <6; 9 = ≥2 and <4; 10 = <2	[29,95,97,98,103,104]
VENV3	number of disaster events	number of flood events	number of flood events each year	1	10	1 = ≥18; 2 = ≥16 and <18; 3 = ≥14 and <16; 4 = ≥12 and <14; 5 = ≥10 and <12; 6 = ≥8 and <10; 7 = ≥ 6 and <8; 8 = ≥4 and <6; 9 = ≥2 and <4; 10 = <2	[29,95,97,98,103,104]
VENV4	water quality	number of villages where rivers are polluted by sewage	percentage of villages in each district whose rivers are polluted by sewage	1	10	1 = ≥10; 2 = ≥9 and <10; 3 = ≥8 and <9; 4 = ≥7 and <8; 5 = ≥6 and <7; 6 = ≥5 and <6; 7 = ≥ 4 and <5; 8 = ≥3 and <4; 9 = ≥2 and <3; 10 = <1	[29,57,94–97,99,101,103,104]
VENV5	degradation	number of villages where soil contamination has occurred due to industry	percentage of villages in each district where soil contamination has occurred due to industry	1	10	1 = ≥10; 2 = ≥9 and <10; 3 = ≥8 and <9; 4 = ≥7 and <8; 5 = ≥6 and <7; 6 = ≥5 and <6; 7 = ≥ 4 and <5; 8 = ≥3 and <4; 9 = ≥2 and <3; 10 = <1	[29,57,94–105]
VENV6	degradation	built-up area	percentage of built-up land compared to total land in each sub-district	1	10	1 = ≥36; 2 = ≥32 and <36; 3 = ≥28 and <32; 4 = ≥24 and <28; 5 = ≥20 and <24; 6 = ≥16 and <20; 7 = ≥12 and <16; 8 = ≥8 and <12; 9 = ≥4 and <8; 10 = <4	[29,57,97,99,101,105]
VENV7	disaster mitigation	number of villages that have an early warning system for natural disasters	percentage of villages in each district that have an early warning system for natural disasters	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[29,96,97,101,103]
VENV8	disaster mitigation	number of villages that have normalization programs for rivers, canals, embankments, ditches, or drainage	percentage of villages in each district that have normalization programs for rivers, canals, embankments, ditches, or drainage	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[29,96,101,103]
VENV9	water spring	number of villages that have springs	percentage of villages in each district that have springs	1	10	10 = ≥90; 9 = ≥80 and <90; 8 = ≥70 and <80; 7 = ≥60 and <70; 6 = ≥50 and <60; 5 = ≥40 and <50; 4 = ≥30 and <40; 3 = ≥20 and <30; 2 = ≥10 and <20; 1 = <10	[57,97,99]

Table 2. *Cont.*

Code	Themes	Variables	Sub-Variables	Bad	Good	Description	References
VENV10	degradation	number of villages that have a community custom of burning fields for agricultural purposes	percentage of villages in each district that have a community custom of burning fields for agricultural purposes	1	10	1 = ≥45; 2 = ≥40 and <45; 3 = ≥35 and <40; 4 = ≥30 and <35; 5 = ≥25 and <30; 6 = ≥20 and <25; 7 = ≥ 15 and <20; 8 = ≥10 and <15; 9 = ≥5 and <10; 10 = <5	[95,103]
VENV11	agriculture	areas of agriculture and plantations	percentage of the areas of agriculture and plantations compared to the total land in each district	1	10	1 = ≥45; 2 = ≥40 and <45; 3 = ≥35 and <40; 4 = ≥30 and <35; 5 = ≥25 and <30; 6 = ≥20 and <25; 7 = ≥ 15 and <20; 8 = ≥10 and <15; 9 = ≥5 and <10; 10 = <5	[29,57,97,99,101,105]

3.3. Analysis Methods

In this study, the sustainability analysis conducted using the Rapfish method included several stages, namely (1) determining the attributes/criteria for each dimension of sustainability through a literature review; (2) the assessment of the attributes/criteria for each dimension of sustainability; (3) index and sustainability status assessment through ordination analysis using MDS, leverage analysis, and Monte Carlo analysis.

a Multidimensional Scaling (MDS)

MDS is a multivariate analysis tool used to determine the closeness/similarity of relationships between objects in a multidimensional manner and is based on assessments/perceptions related to closeness/similarity. The ordination technique in MDS places objects in a sequence of measured attributes and basically carries out a multidimensional transformation into lower/simple dimensions.

The MDS approach is used to deliver thorough, quick, and impartial findings regarding the sustainability of watersheds and has advantages compared to other multivariate analyses such as factor analysis and multi-attribute theory, which do not produce stable outputs [70].

Data pertaining to the social, economic, and environmental dimensions were processed using the MDS technique, where, in principle, the data are mapped to the perceived distance between one unit and another unit using scoring. The scoring is determined based on experience, where the minimum score is 1 (bad) and the maximum is 10 (good).

After scoring, an ordination analysis was then carried out and the results plotted on a two-dimensional curve, where the horizontal (x-axis) has indicators from bad (B) to good (G), while the Y-axis has indicators from down (D) to up (U), only provides variation, and is not related at all to the degree of sustainability.

The values of the sustainability index, created by Columbia University in Canada, are shown in Table 3.

Table 3. Sustainability index categories.

Index	Categories
0.00–25.00	not sustainable
25.01–50.00	less sustainable
50.01–75.00	reasonably sustainable
75.01–100.00	sustainable

b Leveraging Analysis

This analysis aims to detect the dominance of variables and examine whether there is a change in ordination (bad and good positions) when these variables are removed one by one, so it is expected that the constructed variables will truly reflect the assessed themes and dimensions. In other words, leverage also shows sensitivity analysis, where the length of the bar shows the magnitude of the influence of the variable in the bad–good ordination, and the size of number shows the percentage difference if the variable is removed from the ordination position. Kavanagh and Pitcher (2004) and Fauzi (2019) [62] state that errors in Rapfish can occur due to various factors, including the following:

- Errors in determining variable scores;
- The variables used may not be appropriate for the theme being built.

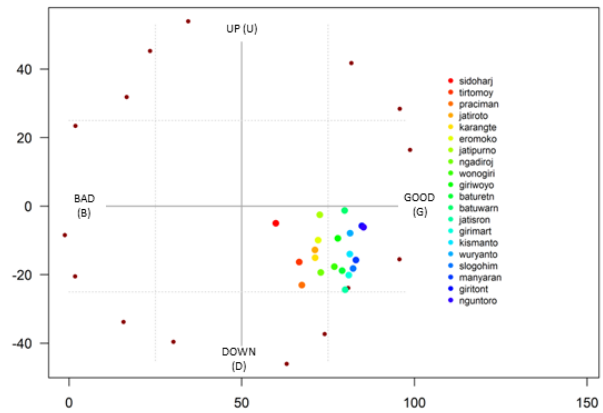
c Monte Carlo Analysis

This analysis was carried out to detect sources of errors of diversity. The Monte Carlo graph shows that the wider the dot distribution, the higher the disturbance, and conversely, the narrower the distribution, the lower the disturbance. The results of the analysis are shown in the following section.

4. Results and Discussion

4.1. Social Dimension

In the social dimension, the sustainability status of the Upstream Bengawan Solo Watershed is as follows: in 2007, there are 8 districts with reasonably sustainable and 12 with sustainable statuses; in 2019, there are 2 districts with reasonably sustainable and 18 with sustainable statuses; and in 2021, there is 1 district with a reasonably sustainable status and there are 19 with sustainable statuses. This indicates that the change in sustainability values from 2007 to 2021 led to sustainable conditions, which is visually represented by the movement of points from left to right, namely from bad (B) in 2007 to good (G) in 2021 (Figure 2).



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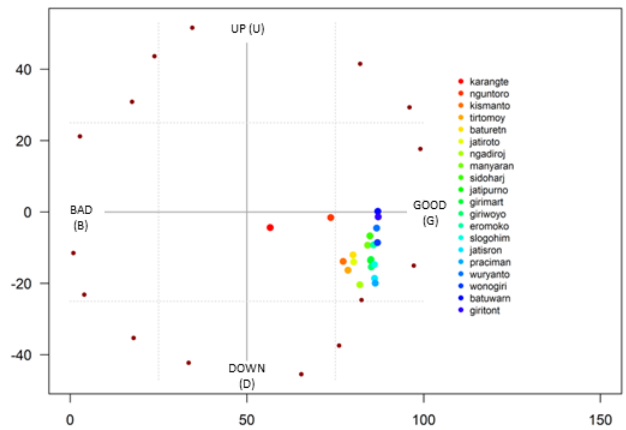
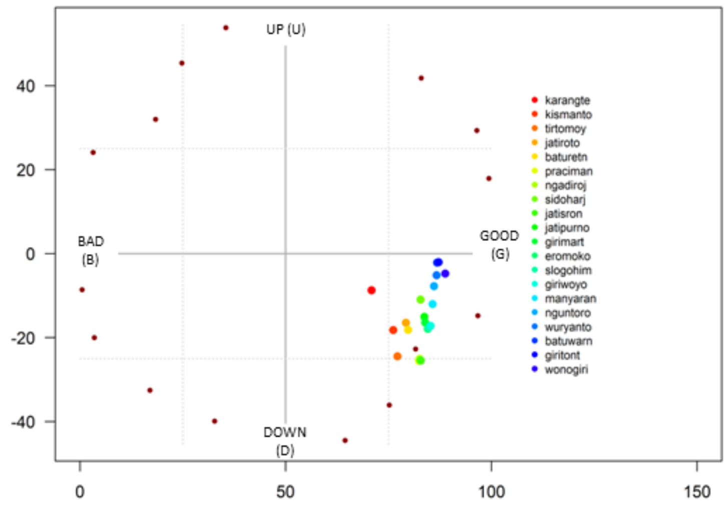


(**b**)

Figure 2. *Cont.*



(**c**)

Figure 2. (**a**) Ordination of social sustainability dimension in 2007; (**b**) ordination of social sustainability dimension in 2019; (**c**) ordination of social sustainability dimension in 2021.

The most sensitive attributes in determining sustainability in the social dimension in 2007, 2019, and 2021 are health facilities, sanitation facilities, and population density (Figure 3). Based on data from the Central Statistics Agency from 2007 to 2021, there has been an increase in the number of hospitals, namely in the Selogiri and Wonogiri districts. Regarding sanitation facilities, there has been an increasing number of toilets such that, in 2021, the entire population had access to them (100%).

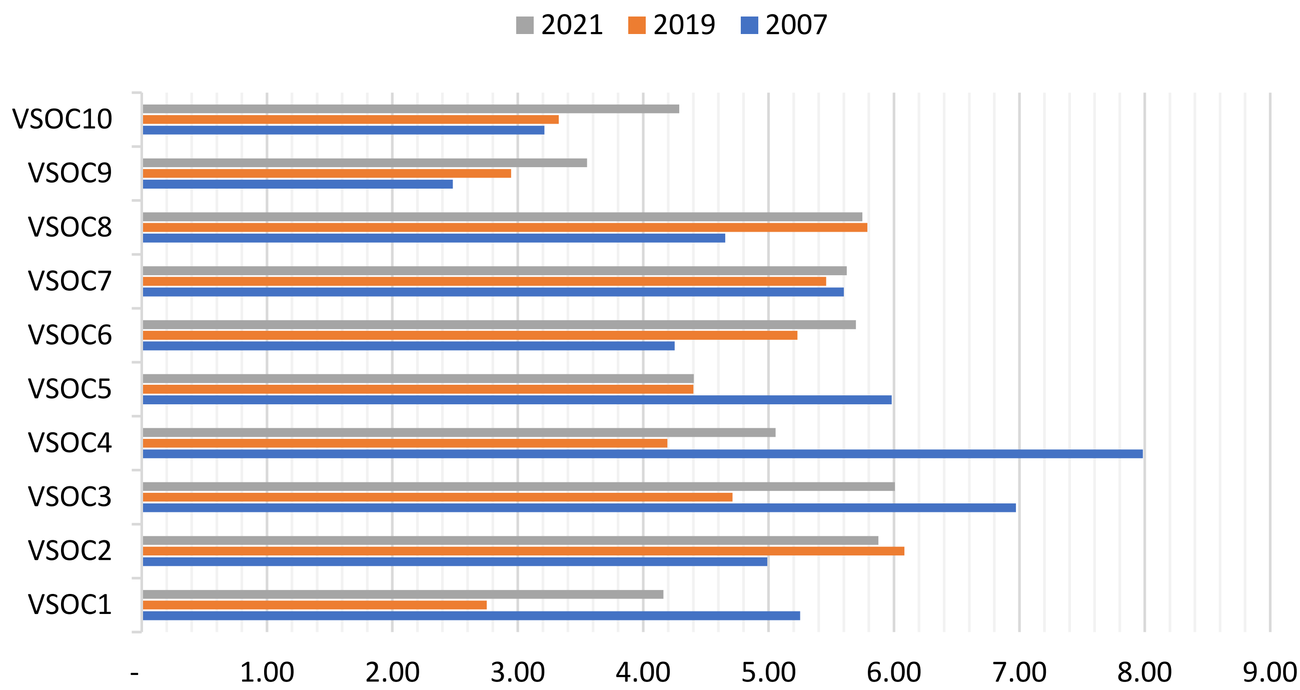


Figure 3. Leverage of social sustainability dimension in 2007, 2019, and 2021.

The results of the Monte Carlo analysis (Figure 4) show that the distribution of units tends to be dense and not wide, which indicates insignificant disturbances related to the social dimension.

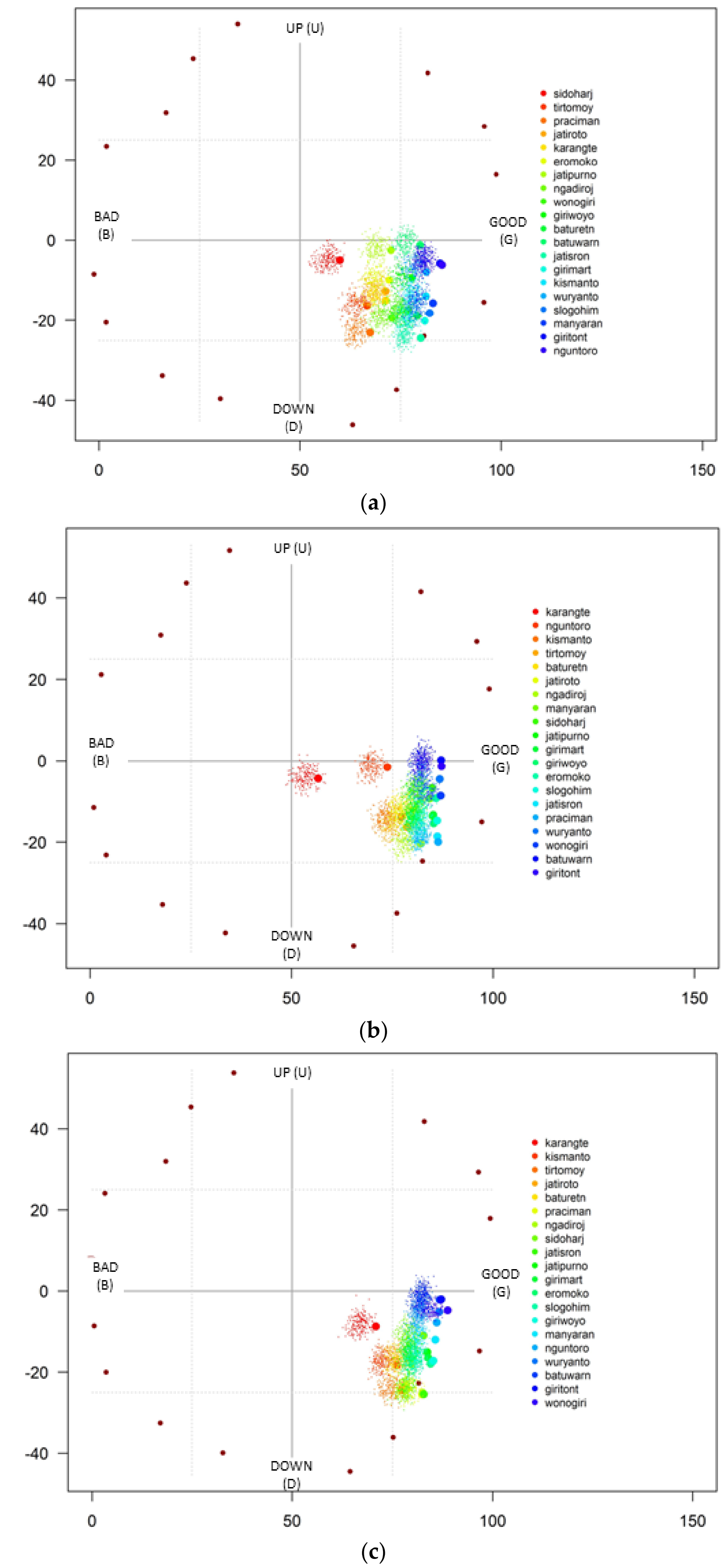
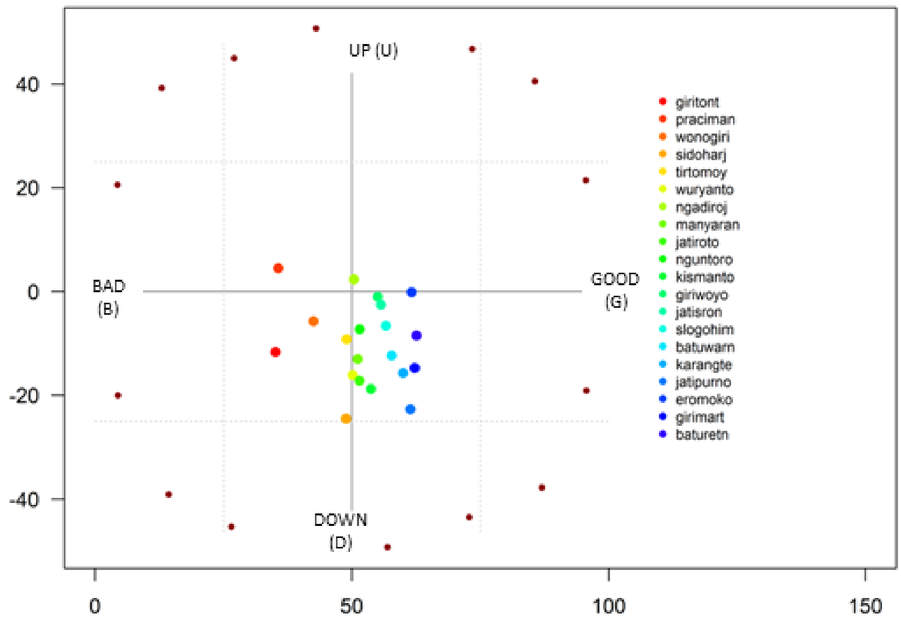


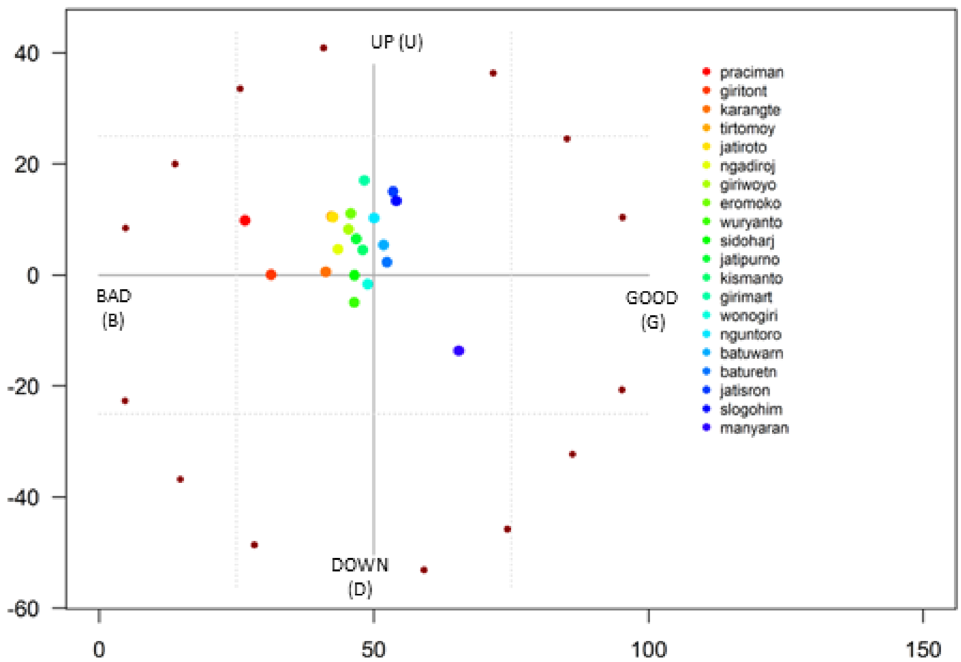
Figure 4. (**a**) Monte Carlo results of social sustainability dimension in 2007; (**b**) Monte Carlo results of social sustainability dimension in 2019; (**c**) Monte Carlo results of social sustainability dimension in 2021.

4.2. Economic Dimension

In the economic dimension, the sustainability status of the Upstream Bengawan Solo Watershed was as follows: in 2007, there are 5 districts with less sustainable and 15 with reasonably sustainable statuses; in 2019, there are 14 districts with reasonably sustainable and 6 with reasonably sustainable statuses; and in 2021, there are 3 districts with less sustainable and 17 with reasonably sustainable statuses. This indicates that the change in sustainability values from 2007 to 2021 led to sustainable conditions, which is visually represented by the movement of points from left to right, namely from bad (B) in 2007 to good (G) in 2021 (Figure 5).

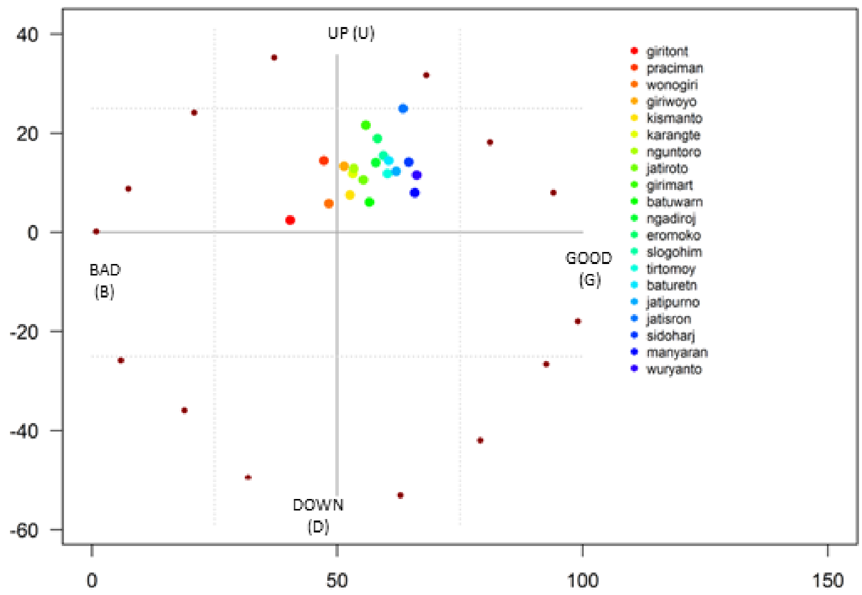


(**a**)



(**b**)

Figure 5. *Cont*.



(**c**)

Figure 5. (**a**) Ordination of economic sustainability dimension in 2007; (**b**) ordination of economic sustainability dimension in 2019; (**c**) ordination of economic sustainability dimension in 2021.

The results of the leverage analysis indicate that the most sensitive attributes in determining sustainability in the economic dimension in 2007, 2019, and 2021 are economic facilities, the agricultural sector, and the use of rivers for irrigation (Figure 6). There was a 53% increase in the number of economic facilities, such as markets, minimarkets, and restaurants. The agriculture, forestry, and fisheries sectors were the most significant contributors to gross regional domestic product from 2010 to 2021, at 28% to 36% [106], and the percentage of villages utilizing rivers for irrigation by 2021 was 84% [107].

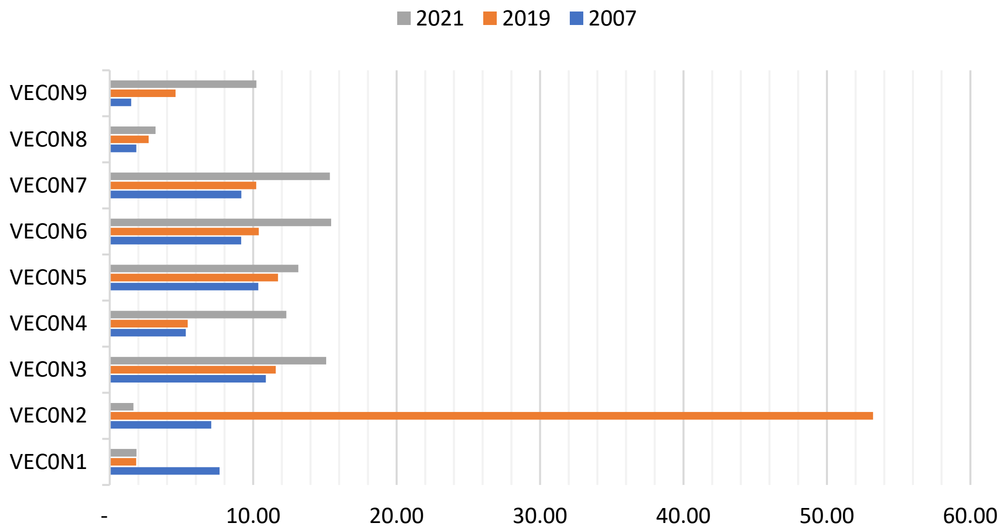
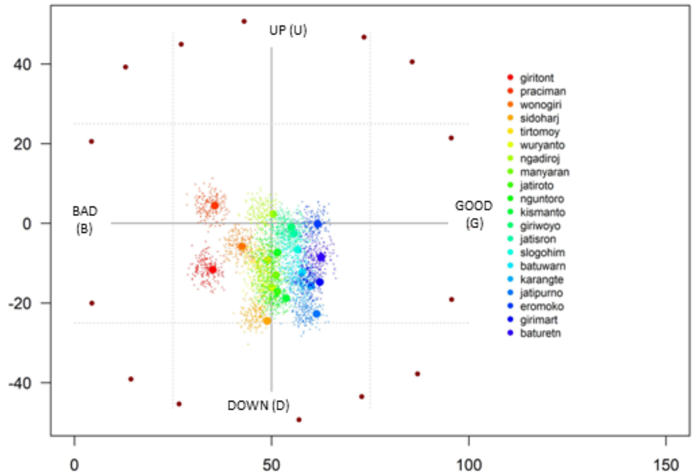


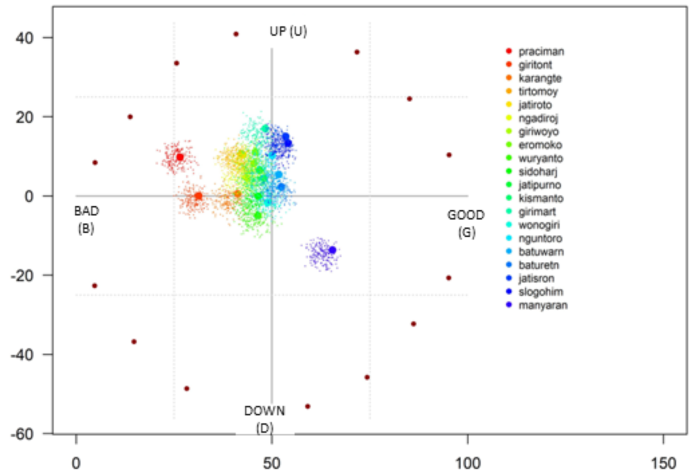
Figure 6. Leverage of economic sustainability dimension in 2007, 2019, and 2021.

There is a variable that stands out, namely VECON2 (percentage of economic facilities), with a leverage value of up to 53%. Based on a review of the data, this was caused by an increase in the number of sub-variables from VECON2, namely the number of traditional markets, the number of restaurants, and the number of modern markets, which increased by 77 units or 43% from 2007 to 2019 [107].

The results of the Monte Carlo analysis (Figure 7) show that the distribution of units tends to be dense and not wide, which indicates insignificant disturbances related to the economic dimension.



(**a**)



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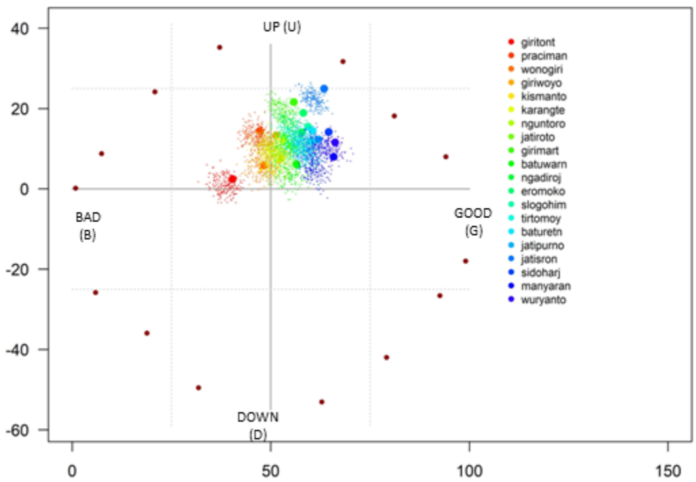
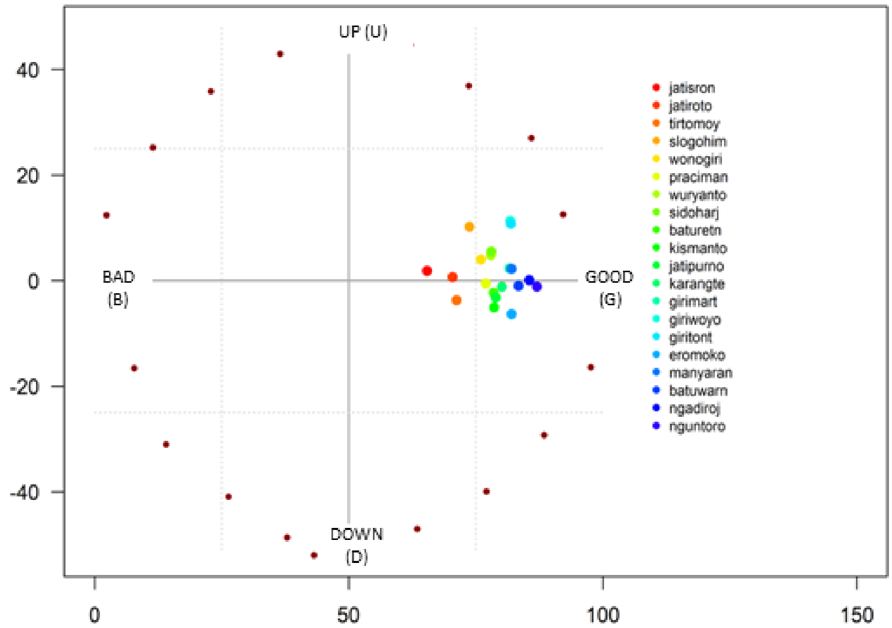


(**c**)

Figure 7. (**a**) Monte Carlo results of economic sustainability dimension in 2007; (**b**) Monte Carlo results of economic sustainability dimension in 2019; (**c**) Monte Carlo results of economic sustainability dimension in 2021.

4.3. Environmental Dimension

In the environmental dimension, the sustainability status of the Upstream Bengawan Solo Watershed was as follows: in 2007, there are 4 districts with reasonably sustainable and 16 with sustainable statuses; in 2019, there are 8 districts with reasonably sustainable and 12 with sustainable statuses; and in 2021, there are 11 districts with reasonably sustainable and 9 with sustainable statuses. This indicates that the sustainability value of the environmental dimension from 2007 to 2021 led to less sustainable conditions, which is visually represented by the movement of points from right to left, namely from good (G) in 2007 to bad (B) in 2021 (Figure 8).



(**a**)

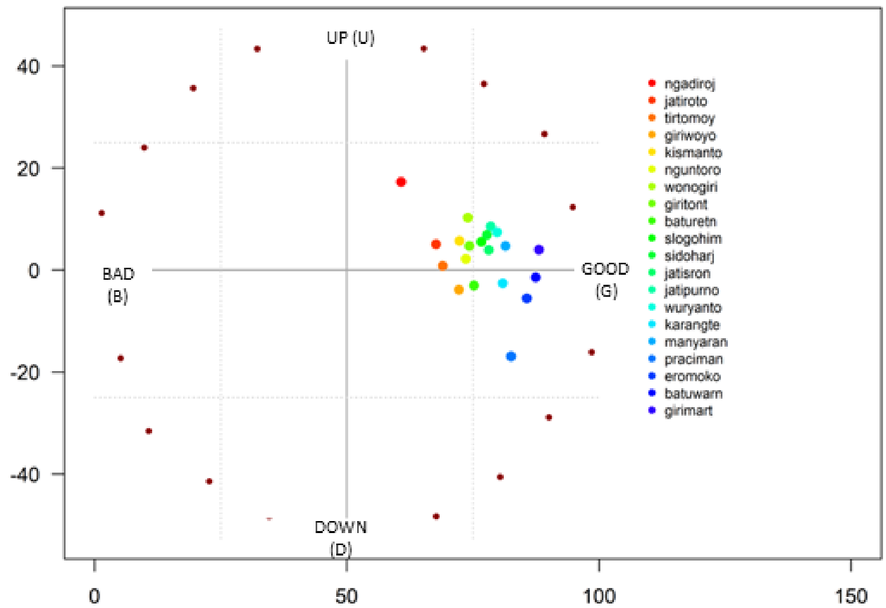


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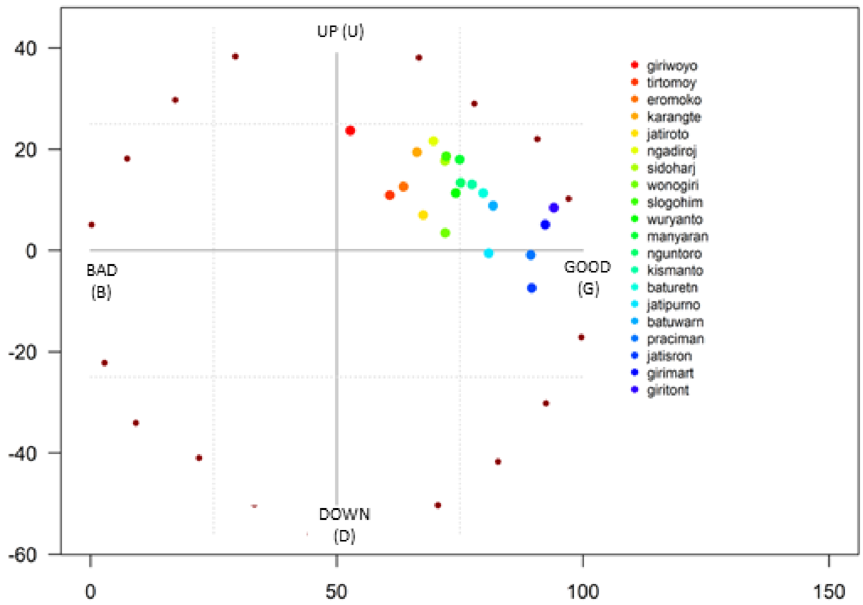
Figure 8. *Cont.*



(**c**)

Figure 8. (**a**) Ordination of environmental sustainability dimension in 2007; (**b**) ordination of environmental sustainability dimension in 2019; (**c**) ordination of environmental sustainability dimension in 2021.

The results of the leverage analysis indicate that the most sensitive attributes in determining the sustainability value in the environmental dimension are the existence of springs, disaster mitigation systems, and river normalization programs (Figure 9). The community needs the disaster mitigation system because most areas in Wonogiri Regency have a high landslide disaster risk. This is because 49% of the soil is lithosol, which is very sensitive to erosion, and the risk is increased by the steep slopes in each sub-district [108]. Drought-prone disaster risk in the Wonogiri Regency is in the high category [109], so water source availability and river normalization programs are important for residents.

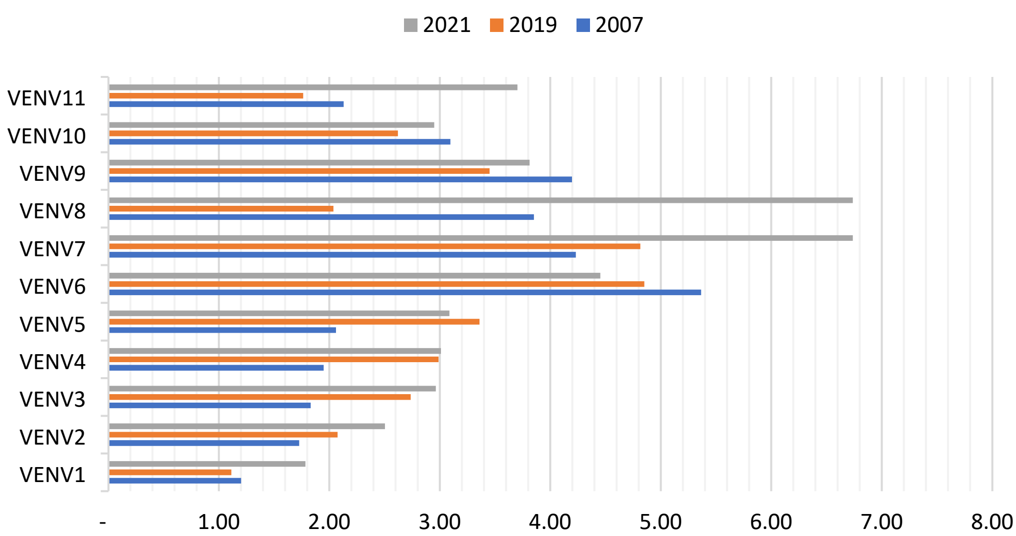


Figure 9. Leverage of environmental sustainability dimension in 2007, 2019, and 2021.

The results of the Monte Carlo analysis (Figure 10) show that the distribution of units tends to be dense and not wide, which indicates insignificant disturbances related to the environmental dimension.

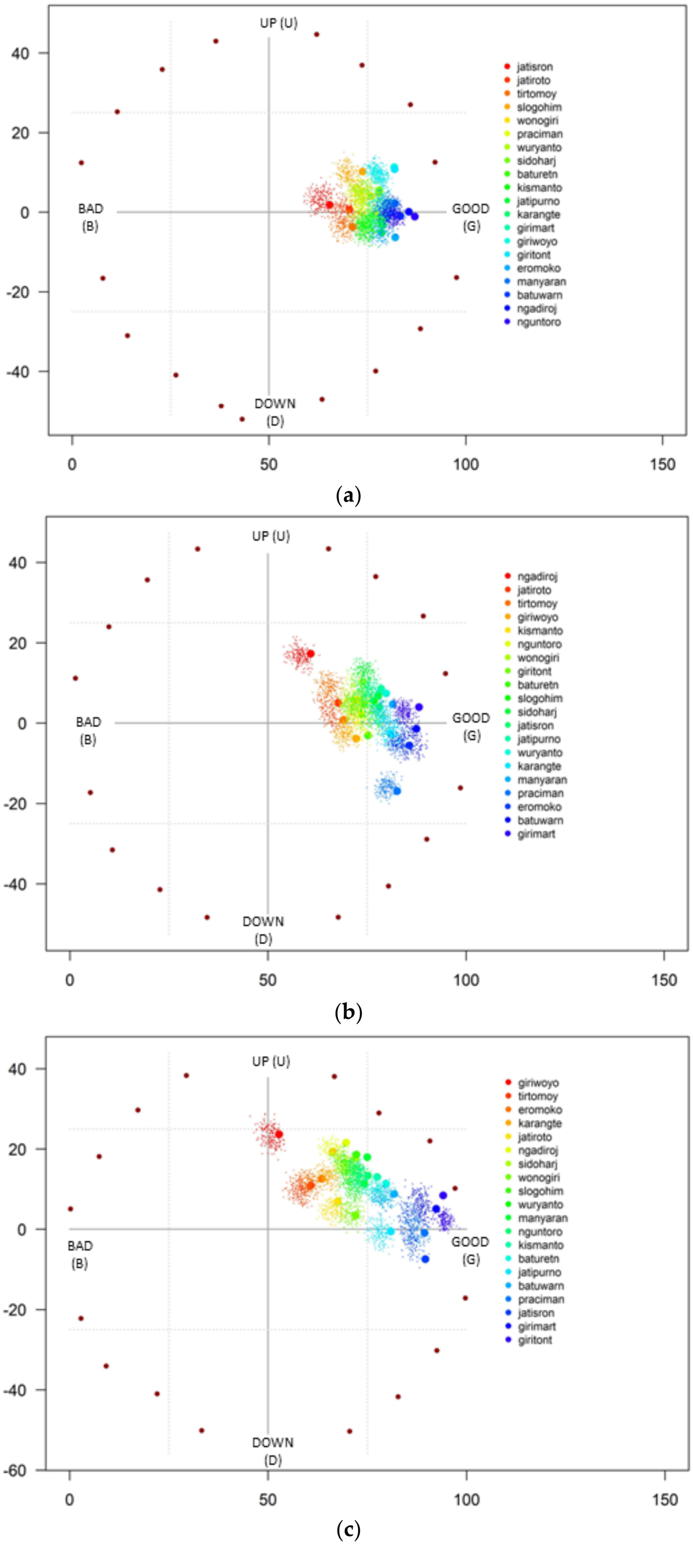


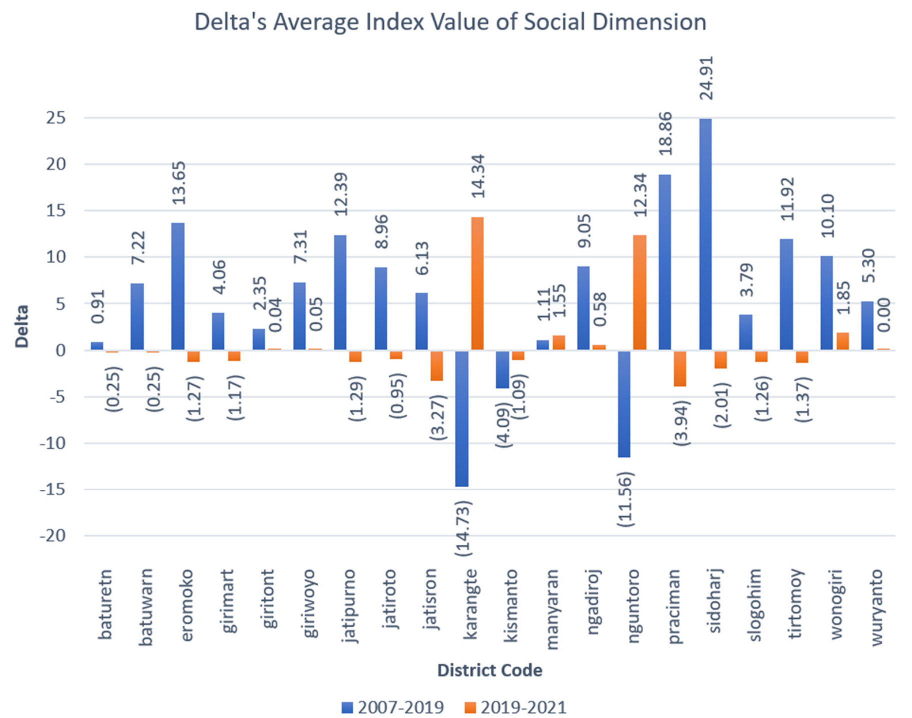
Figure 10. (**a**) Monte Carlo results of environmental sustainability dimension in 2007; (**b**) Monte Carlo results of environmental sustainability dimension in 2019; (**c**) Monte Carlo results of environmental sustainability dimension in 2021.

4.4. Multidimensional Scaling

The average results of the social dimension index tend to increase from 2007 to 2019 and 2021. This illustrates that regarding health, population, the use of government land, and the use of social facilities, the impact of changing conditions is lessening. These improvements can be supported by better and fairer government programs that can be utilized by the community.

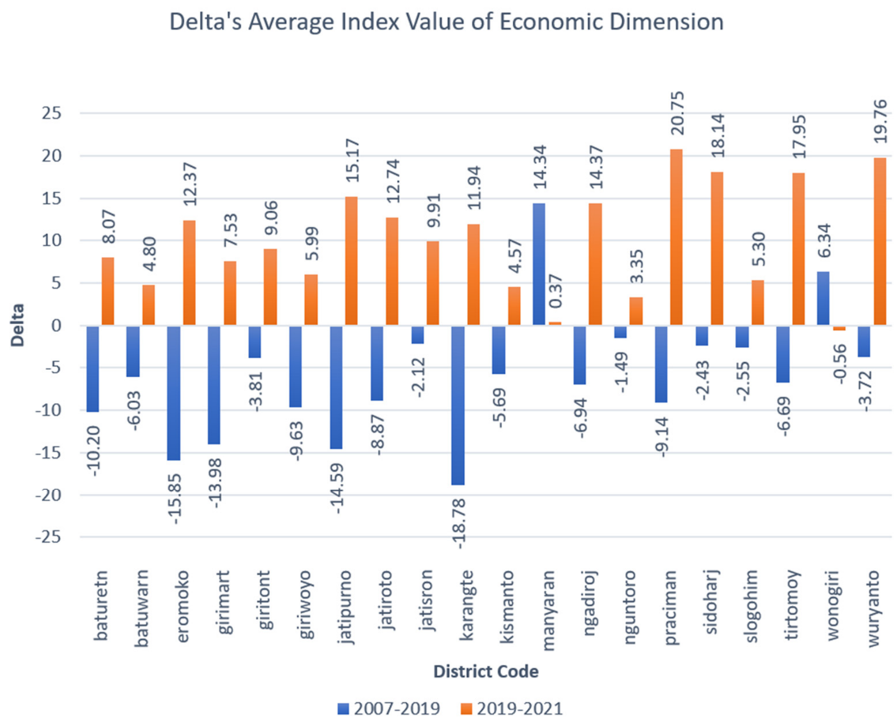
While the economic dimension tends to fluctuate, a decrease occurred from 2007 to 2019 and then increased in 2021. This indicates that human economic activities such as industry, agriculture, tourism, transportation, and mining, along with the condition of facilities and utilization of irrigation infrastructure, are experiencing fluctuating conditions. A decline in 2019 is identified because sectors relevant to space utilization in watershed areas, such as agriculture, forestry, and fisheries, experienced an economic contraction of minus 0.15 percent based on the Wonogiri Regency GRDP Document of 2015–2019 [110].

This is very different when compared to the environmental dimension, which experienced a decline from 2007 to 2019 and 2021. Environmental conditions such as forestry, disasters, water quality, the availability of water resources, and agricultural land conditions experienced a decline in quality and quantity. For example, in 2007, there were 71 landslide incidents, and there were 81 incidents in 2021, and the number of villages with springs decreased from 139 in 2007 to 121 in 2021. However, the decrease in the average value on a regional scale did not necessarily occur evenly in individual districts; for example, of 20 districts, there were 14 for which the values decreased and 6 for which they increased. Based on data checking, for all variables forming the environmental dimension—including converted forest area (square meters), the number of landslide events (%), the number of flood events (%), the number of villages where rivers are polluted by sewage (%), the number of villages where soil contamination has occurred due to industry (%), built-up areas (%), the number of villages that have an early warning system for natural disasters (%), the number of villages that have normalization programs for rivers, canals, dams, ditches, drainage, the number of villages that have springs (unit), the number of villages that have a community custom of burning fields for agriculture (%), agricultural and plantation areas (%)—in six districts (Baturetno, Girimarto, Giritontro, Jatipurno, Jatisrono, and Pracimantoro), the weighting score tends to increase; in other words, the condition of the six districts in the environmental dimension tends to improve from 2007 to 2021 (Table 4 and Figure 11) [107].



(**a**)

Figure 11. *Cont.*



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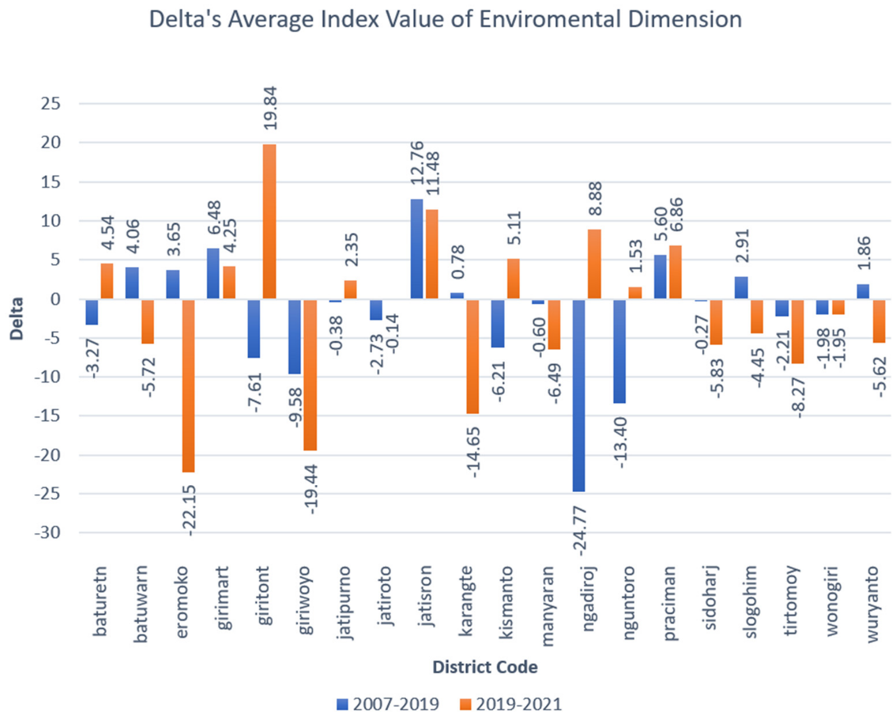


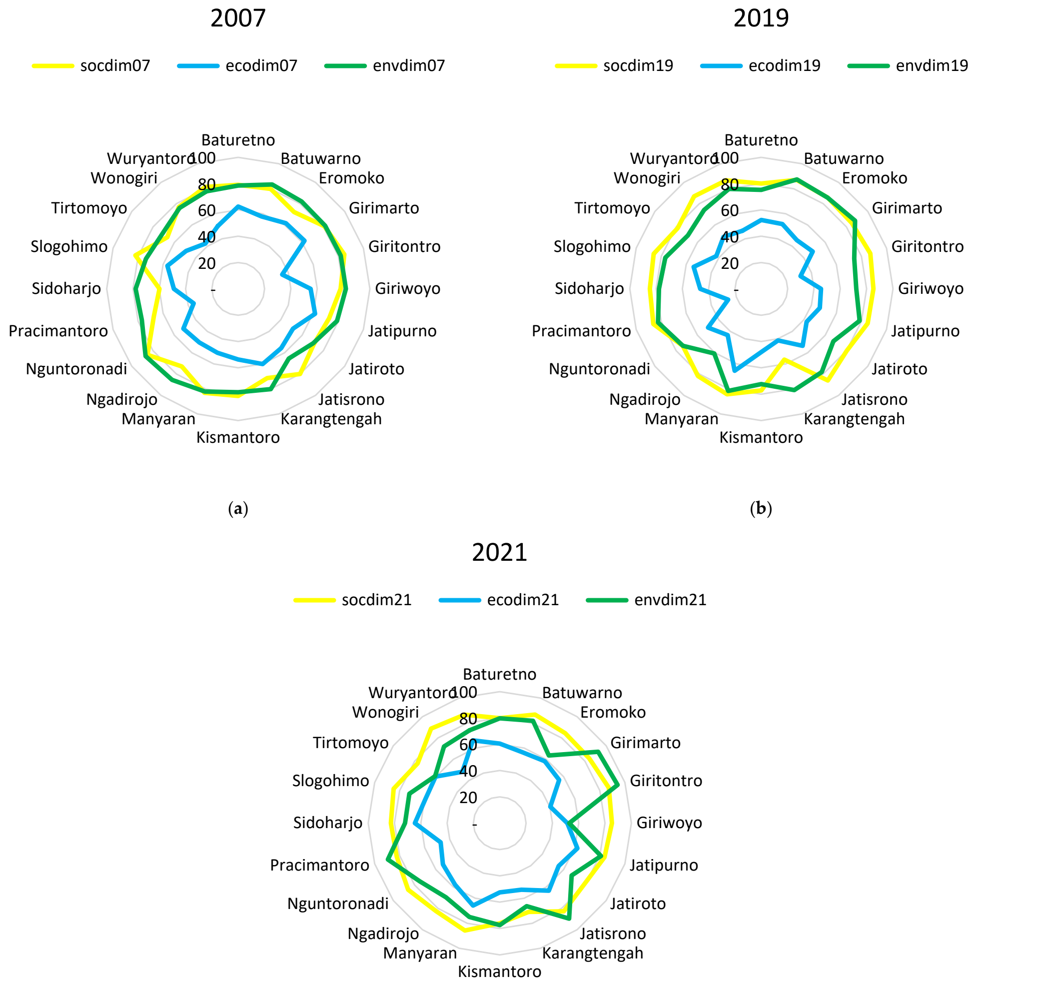
(**c**)

Figure 11. (**a**) Delta's average index value for social dimension; (**b**) Delta's average index value for economic dimension; (**c**) Delta's average index value for environmental dimension.

The radar diagrams below indicate that the social dimension has the highest sustainability value compared to the economic and environmental dimensions in 2007, 2019, and 2021. For the environmental dimension, the sustainability value decreases from 2007 to 2019 and 2021, while for the economic dimension, it experiences a downward trend in 2019 and an increasing trend in 2021 (Figure 12).

Table 4. Average index values of social, economic, and environmental dimensions of sustainability.

District Code	District	Social Dimension			Economic Dimension			Environmental Dimension		
		2007	2019	2021	2007	2019	2021	2007	2019	2021
baturetn	Baturetno	79.11	80.02	79.77	62.58	52.39	60.45	78.49	75.23	79.77
batuwarn	Batuwarno	79.83	87.05	86.80	57.76	51.73	56.53	83.41	87.47	81.75
eromoko	Eromoko	72.14	85.79	84.52	61.65	45.80	58.17	82.03	85.69	63.53
girimart	Girimarto	81.02	85.08	83.91	62.25	48.26	55.79	81.63	88.11	92.36
giritont	Giritontro	84.79	87.14	87.18	35.11	31.30	40.36	81.88	74.27	94.11
giriwoyo	Giriwoyo	77.86	85.16	85.21	55.00	45.37	51.37	81.80	72.22	52.77
jatipurno	Jatipurno	72.59	84.97	83.69	61.39	46.79	61.97	78.91	78.53	80.88
jatiroto	Jatiroto	71.22	80.19	79.23	51.45	42.59	55.33	70.43	67.70	67.56
jatisron	Jatisrono	79.97	86.10	82.84	55.63	53.52	63.43	65.40	78.16	89.63
karangte	Karangtengah	71.28	56.55	70.89	60.00	41.23	53.17	80.14	80.92	66.28
kismanto	Kismantoro	81.31	77.21	76.13	53.69	48.00	52.57	78.57	72.36	77.47
manyaran	Manyaran	83.05	84.16	85.70	51.09	65.43	65.81	82.06	81.46	74.97
ngadiroj	Ngadirojo	72.89	81.94	82.52	50.39	43.45	57.82	85.53	60.76	69.64
nguntoro	Nguntoronadi	85.28	73.72	86.06	51.50	50.01	53.36	87.02	73.62	75.15
praciman	Pracimantoro	67.44	86.30	82.37	35.62	26.49	47.23	76.98	82.58	89.44
sidoharj	Sidoharjo	59.87	84.78	82.77	48.87	46.45	64.58	78.06	77.80	71.97
slogohim	Slogohimo	82.26	86.04	84.78	56.64	54.10	59.40	73.75	76.66	72.22
tirtomoy	Tirtomoyo	66.64	78.56	77.19	48.98	42.29	60.24	71.23	69.02	60.75
wonogiri	Wonogiri	76.82	86.93	88.78	42.51	48.85	48.29	75.98	73.99	72.04
wuryanto	Wuryantoro	81.39	86.69	86.69	50.13	46.41	66.17	77.96	79.82	74.20
mean		76.34	82.22	82.85	52.61	46.52	56.60	78.56	76.82	75.33



(c)

Figure 12. (**a**) Radar chart of social, economic, and environmental sustainability dimensions in 2007; (**b**) radar chart of social, economic, and environmental sustainability dimensions in 2019; (**c**) radar chart of social, economic, and environmental sustainability dimensions in 2021.

5. Conclusions

The average index results for the social dimension tend to increase from 2007 to 2019 and 2021. This illustrates that regarding health, population, the use of government land, and the use of social facilities, the impact of changing conditions is lessening. These improvements can be supported by better and fairer government programs that can be utilized by the community. While the economic dimension tends to fluctuate. A decrease occurs from 2007 to 2019 and then increases in 2021. This indicates that human economic activities such as industry, agriculture, tourism, transportation, and mining, along with the condition of facilities and utilization of irrigation infrastructure, are experiencing fluctuating conditions. A decline in 2019 is identified because sectors relevant to space utilization in watershed areas, such as agriculture, forestry, and fisheries, experienced an economic contraction of minus 0.15 percent. This is considerably different compared to the environmental dimension, which experienced a decline from 2007 to 2019 and 2021. Environmental conditions such as forestry, disasters, water quality, the availability of water resources, and agricultural land conditions experienced a decline in quality and quantity. For example, in 2007, there were 71 landslides, and there were 81 in 2021, and the number of villages with springs fell from 139 in 2007 to 121 in 2021.

The sustainability scores were compared between regions in terms of their sustainability performance. For the social dimension, the highest is in the Giritontro district and the lowest is in the Karangtengah district; for the economic dimension, the highest is in the Manyaran district and the lowest is in the Giritontro district; and for the environmental dimension, the highest is in the Girimarto district and the lowest is in the Tirtomoyo district. The lessons learned here can be incorporated into regional policies and actions to address issues encountered during the implementation phase.

This research improves upon previous studies on watershed sustainability measurements conducted by Widicahyono (2020) [16], Murdiyanto (2016) [17], Hamzah (2016) [18], and Syamsiyah (2023) [19], which were limited to the one period. Furthermore, the sustainability values provide straightforward information about which components contribute to regional development the most and can be used to assess the success of policymakers in implementing development programs.

This study's findings highlight a few important observations that illustrate the complexity of problems in the Upstream Bengawan Solo Watershed that require integrated planning and management by cross-agency groups and stakeholders. This research still has shortcomings, so further studies are needed, such as those identifying and mapping the influence of smaller areas at the village level, studying suitability through spatial planning, and formulating policies and space utilization programs in watersheds. Furthermore, policies and measures are needed to sustain watersheds, such as Erosion and Sedimentation Control, Sustainable Forest and Land Management, Water Resource Management, and Institutional Social Management.

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References

1. The Ministry of Public Works and Public Housing. *Studi Penanganan Sedimentasi Waduk Serbaguna Wonogiri*; Japan International Cooperation Agency: Tokyo, Japan, 2007.
2. Libriyanto, O.; Pravitasari, A.E.; Ardiansyah, M. Dynamics and Predictions of Land-Use Changes in Serang Raya and Their Conformity to the Spatial Plan of Banten Province. *J. Geogr.* **2022**, *14*, 33. [CrossRef]
3. The Ministry of Agrarian and Spatial Planning. *Peraturan Menteri ATR-KBPN Nomor 21 Tahun 2021 Tentang Pelaksanaan Pengendalian Pemanfaatan Ruang dan Pengawasan Penataan Ruang*; The Ministry of Agrarian and Spatial Planning: Jakarta Selatan, Indonesia, 2021.
4. Yi, H.; Güneralp, B.; Kreuter, U.P.; Güneralp, İ.; Filippi, A.M. Spatial and Temporal Changes in Biodiversity and Ecosystem Services in the San Antonio River Basin, Texas, from 1984 to 2010. *Sci. Total Environ.* **2018**, *619–620*, 1259–1271. [CrossRef]
5. Hosseini, S.M.; Parizi, E.; Ataie-Ashtiani, B.; Simmons, C.T. Assessment of Sustainable Groundwater Resources Management Using Integrated Environmental Index: Case Studies across Iran. *Sci. Total Environ.* **2019**, *676*, 792–810. [CrossRef] [PubMed]
6. Yin, D.; Li, X.; Li, G.; Zhang, J.; Yu, H. Spatio-Temporal Evolution of Land Use Transition and Its Eco-Environmental Effects: A Case Study of the Yellow River Basin, China. *Land* **2020**, *9*, 514. [CrossRef]
7. Yang, Y.; Li, M.; Feng, X.; Yan, H.; Su, M.; Wu, M. Spatiotemporal Variation of Essential Ecosystem Services and Their Trade-off/Synergy along with Rapid Urbanization in the Lower Pearl River Basin, China. *Ecol. Indic.* **2021**, *133*, 108439. [CrossRef]
8. Fauzi, A. *Ekonomi Perikanan Teori, Kebijakan, dan Pengelolaan*; PT Gramedia Pustaka Utama: Jakarta, Indonesia, 2010; ISBN 978-979-22-6278-0.
9. Saridewi, T.R.; Hadi, S.; Fauzi, A.; Rusastra, I.W. Penataan Ruang Daerah Aliran Sungai Ciliwung dengan Pendekatan Kelembagaan dalam Perspektif Pemantapan Pengelolaan Usahatani. *Forum Penelit. Agro Ekon.* **2014**, *32*, 87. [CrossRef]
10. Akhter, S.; Eibek, K.U.; Islam, S.; Towfiqul Islam, A.R.M.; Chu, R.; Shuanghe, S. Predicting Spatiotemporal Changes of Channel Morphology in the Reach of Teesta River, Bangladesh Using GIS and ARIMA Modeling. *Quat. Int.* **2019**, *513*, 80–94. [CrossRef]
11. Meng, S.; Huang, Q.; Zhang, L.; He, C.; Inostroza, L.; Bai, Y.; Yin, D. Matches and Mismatches between the Supply of and Demand for Cultural Ecosystem Services in Rapidly Urbanizing Watersheds: A Case Study in the Guanting Reservoir Basin, China. *Ecosyst. Serv.* **2020**, *45*, 101156. [CrossRef]
12. Cho, Y.-C.; Im, J.-K.; Han, J.; Kim, S.-H.; Kang, T.; Lee, S. Comprehensive Water Quality Assessment Using Korean Water Quality Indices and Multivariate Statistical Techniques for Sustainable Water Management of the Paldang Reservoir, South Korea. *Water* **2023**, *15*, 509. [CrossRef]
13. Kim, M.-A.; Na, E.; Park, S.; Kang, T.; Lee, S. Assessment of Water Quality Target Attainment and Influencing Factors Using the Multivariate Log-Linear Model in the Nakdong River Basin, Republic of Korea. *Sustainability* **2021**, *13*, 11094. [CrossRef]
14. Jovovic, R.; Draskovic, M.; Delibasic, M.; Jovovic, M. The Concept of Sustainable Regional Development–Institutional Aspects, Policies and Prospects. *J. Int. Stud.* **2017**, *10*, 255–266. [CrossRef]
15. Pravitasari, A.E.; Saizen, I.; Kyoto University; Rustiadi, E. Bogor Agricultural University towards Resilience of Jabodetabek Megacity: Developing Local Sustainability Index with Considering Local Spatial Interdependency. *J-SustaiN* **2016**, *4*, 27–34. [CrossRef] [PubMed]
16. Widicahyono, A. Evaluasi dan Rekonstruksi Keberlanjutan Model Imbal Jasa Lingkungan di Sub DAS Cebong. Ph.D. Dissertation, Universitas Gajah Mada, Yogyakarta, Indonesia, 2020.
17. Murdiyanto, D. Model Spasial Ekologis Penggunaan Lahan Untuk Pengendalian Degradasi Lahan Di Hulu DAS Tondano Sulawesi Utara. Ph.D. Dissertation, Universitas Gajah Mada, Yogyakarta, Indonesia, 2016.
18. Maarif, M.S.; Etty, R. Mitigasi Risiko Pengelolaan Sumber Daya Air Waduk Jatiluhur Dengan Pendekatan Green Business Continuity Management (GBCM). Doctoral Dissertation, Institut Pertanian Bogor, Bogor, Indonesia, 2016.
19. Syamsiyah, N.; Sulistyowati, L.; Noor, T.I.; Setiawan, I. The Sustainability Level of an EcoVillage in the Upper Citarum Watershed of West Java Province, Indonesia. *Sustainability* **2023**, *15*, 15951. [CrossRef]
20. Núñez-Razo, I.; De Anda, J.; Barrios-Piña, H.; Olvera-Vargas, L.A.; García-Ruíz-García, M.; Hernández-Morales, S. Development of a Watershed Sustainability Index for the Santiago River Basin, Mexico. *Sustainability* **2023**, *15*, 8428. [CrossRef]

21. Geng, J.; Yu, K.; Xie, Z.; Zhao, G.; Ai, J.; Yang, L.; Yang, H.; Liu, J. Analysis of Spatiotemporal Variation and Drivers of Ecological Quality in Fuzhou Based on RSEI. *Remote Sens.* **2022**, *14*, 4900. [CrossRef]
22. Li, W.; He, G.; Zhao, Y.; Liu, Z.; He, F.; Wang, H. An Analysis of Runoff Variation in a Small Basin in the Loess Plateau: Identifying the Variation Causes and Implications for Sustainable Water Management. *Sustainability* **2023**, *15*, 9651. [CrossRef]
23. Liang, X.; Pan, Y.; Li, C.; Wu, W.; Huang, X. Evaluating the Influence of Land Use and Landscape Pattern on the Spatial Pattern of Water Quality in the Pearl River Basin. *Sustainability* **2023**, *15*, 15146. [CrossRef]
24. Lu, Y.; Zhou, M.; Ou, G.; Zhang, Z.; He, L.; Ma, Y.; Ma, C.; Tu, J.; Li, S. Sustainable Land-Use Allocation Model at a Watershed Level under Uncertainty. *Int. J. Environ. Res. Public Health* **2021**, *18*, 13411. [CrossRef]
25. Barbier, E.B. The Concept of Sustainable Economic Development. *Environ. Conserv.* **1987**, *14*, 101–110. [CrossRef]
26. Basiago, A.D. Economic, Social, and Environmental Sustainability in Development Theory and Urban Planning Practice. *Environmentalist* **1999**, *19*, 145–161. [CrossRef]
27. Purvis, B.; Mao, Y.; Robinson, D. Three Pillars of Sustainability: In Search of Conceptual Origins. *Sustain. Sci.* **2019**, *14*, 681–695. [CrossRef]
28. World Commission on Environment and Development. *Our Common Future*; Oxford Paperbacks: Oxford, UK, 1987; ISBN 978-0-19-282080-8.
29. Strezov, V.; Evans, A.; Evans, T.J. Assessment of the Economic, Social and Environmental Dimensions of the Indicators for Sustainable Development: Economic, Social and Environmental Dimensions of Sustainability. *Sustain. Dev.* **2017**, *25*, 242–253. [CrossRef]
30. Tuazon, D.; Corder, G.; McLellan, B. Sustainable Development: A Review of Theoretical Contributions. *J-Sustain* **2013**, *1*, 40–48. [CrossRef]
31. United Nations. *United Nations Report of the United Nations Conference on the Human Environment*; United Nations: Stockholm, Sweden, 1972.
32. Meadows, D.; Meadows, D.; Randers, J.; Behrens, W., III. *The Limits to Growth: A Report for the Club of Rome's Project on the Predicament of Mankind*; Universe Books: New York, NY, USA, 1972.
33. Hicks, J. *Value and Capital: An Inquiry into Some Fundamental Principles of Economic Theory*, 2nd ed.; Clarendon Paperbacks; Reprinted; Clarendon Press: Oxford, UK, 2001; ISBN 978-0-19-828269-3.
34. Ruttan, V.W. Constraints on the Design of Sustainable Systems of Agricultural Production. *Ecol. Econ.* **1994**, *10*, 209–219. [CrossRef]
35. Daly, H.E. The Economics of the Steady State. *Am. Econ. Rev.* **1974**, *64*, 15–21.
36. Daly, H.E. *Toward a Steady-State Economy: Edited by Herman E. Daly*; W. H. Freeman: San Francisco, CA, USA, 1973; ISBN 978-0-7167-0799-8.
37. World Bank. *Environmental Aspects of Bank Work*; The World Bank Operations Manual Statements OMS 2.36; World Bank: Washington, DC, USA, 1986.
38. Pearce, D.; Barbier, E.; Markandya, A. *Sustainable Development: Economics and Environment in the Third World*; Reprinted; Earthscan: London, UK, 1997; ISBN 978-1-85383-088-4.
39. Serageldin, I. *Development Partners: Aid and Cooperation in the 1990s*; SIDA: Stockholm, Sweden, 1993; ISBN 978-91-586-7179-9.
40. Goodland, R.; Daly, H. Environmental Sustainability: Universal and Non-Negotiable. *Ecol. Appl.* **1996**, *6*, 1002–1017. [CrossRef]
41. Khan, M.A. Sustainable Development: The Key Concepts, Issues and Implications. Keynote Paper given at the International Sustainable Development Research Conference, 27–29 March 1995, Manchester, UK. *Sustain. Dev.* **1995**, *3*, 63–69. [CrossRef]
42. Lawn, P.A. (Ed.) *Sustainable Development Indicators in Ecological Economics*; Current Issues in Ecological Economics; Elgar: Cheltenham, UK, 2006; ISBN 978-1-84542-099-4.
43. Pollesch, N.L.; Dale, V.H. Normalization in Sustainability Assessment: Methods and Implications. *Ecol. Econ.* **2016**, *130*, 195–208. [CrossRef]
44. Ness, B.; Urbel-Piirsalu, E.; Anderberg, S.; Olsson, L. Categorising Tools for Sustainability Assessment. *Ecol. Econ.* **2007**, *60*, 498–508. [CrossRef]
45. Munda, G. Multiple Criteria Decision Analysis and Sustainable Development. In *Multiple Criteria Decision Analysis: State of the Art Surveys*; International Series in Operations Research & Management Science; Springer: New York, NY, USA, 2005; Volume 78, pp. 953–986, ISBN 978-0-387-23067-2.
46. United Nations. *Agenda 21*; United Nations: Rio de Janerio, Brazil, 1992.
47. Böhringer, C.; Jochem, P.E.P. Measuring the Immeasurable—A Survey of Sustainability Indices. *Ecol. Econ.* **2007**, *63*, 1–8. [CrossRef]
48. Moran, D.D.; Wackernagel, M.; Kitzes, J.A.; Goldfinger, S.H.; Boutaud, A. Measuring Sustainable Development—Nation by Nation. *Ecol. Econ.* **2008**, *64*, 470–474. [CrossRef]
49. Nourry, M. Measuring Sustainable Development: Some Empirical Evidence for France from Eight Alternative Indicators. *Ecol. Econ.* **2008**, *67*, 441–456. [CrossRef]
50. Siche, J.R.; Agostinho, F.; Ortega, E.; Romeiro, A. Sustainability of Nations by Indices: Comparative Study between Environmental Sustainability Index, Ecological Footprint and the Emergy Performance Indices. *Ecol. Econ.* **2008**, *66*, 628–637. [CrossRef]
51. Ram Pillarisetti, J.; Van Den Bergh, J.C.J.M. Aggregate Indices for Identifying Environmentally Responsible Nations: An Empirical Analysis and Comparison. *Int. J. Environ. Stud.* **2013**, *70*, 140–150. [CrossRef]

52. Estoque, R.C.; Murayama, Y. Social–Ecological Status Index: A Preliminary Study of Its Structural Composition and Application. *Ecol. Indic.* **2014**, *43*, 183–194. [CrossRef]
53. Evans, A.; Strezov, V.; Evans, T. Measuring Tools for Quantifying Sustainable Development. *Eur. J. Sustain. Dev.* **2015**, *4*, 291. [CrossRef]
54. Bilbao-Ubillos, J. The Limits of Human Development Index: The Complementary Role of Economic and Social Cohesion, Development Strategies and Sustainability: Limits of Human Development Index. *Sustain. Dev.* **2013**, *21*, 400–412. [CrossRef]
55. Cinelli, M.; Coles, S.R.; Kirwan, K. Analysis of the Potentials of Multi Criteria Decision Analysis Methods to Conduct Sustainability Assessment. *Ecol. Indic.* **2014**, *46*, 138–148. [CrossRef]
56. Bond, A.; Morrison-Saunders, A.; Pope, J. Sustainability Assessment: The State of the Art. *Impact Assess. Proj. Apprais.* **2012**, *30*, 53–62. [CrossRef]
57. Boggia, A.; Cortina, C. Measuring Sustainable Development Using a Multi-Criteria Model: A Case Study. *J. Environ. Manag.* **2010**, *91*, 2301–2306. [CrossRef]
58. Kropp, W.W.; Lein, J.K. Assessing the Geographic Expression of Urban Sustainability: A Scenario Based Approach Incorporating Spatial Multicriteria Decision Analysis. *Sustainability* **2012**, *4*, 2348–2365. [CrossRef]
59. Lombardi, P.; Ferretti, V. New Spatial Decision Support Systems for Sustainable Urban and Regional Development. *Smart Sustain. Built Environ.* **2015**, *4*, 45–66. [CrossRef]
60. López, E.; Monzón, A. Integration of Sustainability Issues in Strategic Transportation Planning: A Multi-Criteria Model for the Assessment of Transport Infrastructure Plans: Integration of Sustainability Issues in Strategic Transportation Planning. *Comput.-Aided Civ. Infrastruct. Eng.* **2010**, *25*, 440–451. [CrossRef]
61. Fauzi, A.; Anna, S. Evaluasi Status Keberlanjutan Pembangunan Perikanan: Aplikasi Pendekatan Rapfish (Studi Kasus Perairan Pesisir DKI Jakarta). *J. Pesisir Dan Lautan PKSPL-IPB* **2002**, *4*, 43–56.
62. Fauzi, A. *Teknik Analisis Keberlanjutan*; Gramedia Pustaka Utama: Jakarta, Indonesia, 2019; ISBN 602-06-3025-0.
63. Suresha Adiga, M.; Ananthan, P.S.; Ramasubramanian, V.; Divya Kumari, H.V. Validating RAPFISH Sustainability Indicators: Focus on Multi-Disciplinary Aspects of Indian Marine Fisheries. *Mar. Policy* **2015**, *60*, 202–207. [CrossRef]
64. Stanny, Y.A.; Barus, B.; Pravitasari, A.E. Sustainability of Horticulture in Agriculture Era 4.0 in Lembang Sub-District, West Java. *IOP Conf. Ser. Earth Environ. Sci.* **2021**, *694*, 012059. [CrossRef]
65. Hartati, H.; Martini, E.S.; Marissa, F.; Ridhowati, S. Sustainability Study of Household Scale Fisheries Management Using RAPFISH Modified Method: A Case Study in Sungsang 1, Banyuasin II District. *Aquac. Aquar. Conserv. Legis.* **2021**, *14*, 953–964.
66. Abdillah, N.; Thamrin, T.; Nofrizal, N.; Wijayanto, G. Quantifying Ecological, Economic, Social, and Governance Attributes for Urban Forest Eco-Tourism Using MDS-RAPFISH Approach. *Int. J. Sustain. Dev. Plan.* **2023**, *18*, 2369–2378. [CrossRef]
67. Chaliluddin, M.A.; Sundari, S.; Rizwan, T.; Zulfahmi, I.; Setiawan, I.; Rahimi, S.A.E.; Nellyana, R. Rapfish: A Rapid Appraisal Technique to Evaluate the Sustainability Status of Pelagic Fisheries in North Aceh Waters. *Jppipa Pendidik. Ipa Fis. Biol. Kim.* **2023**, *9*, 5603–5609. [CrossRef]
68. Santoso, A.B.; Manurung, E.D.; Siagian, D.R.; Purba, H.F.P.; Sembiring, P. Sustainability Study of Horticultural Development in Mandailing Natal District With RAPFISH-MDS Analysis. *Agro Bali. Agric. J.* **2023**, *6*, 286–302. [CrossRef]
69. Idris, I.H.; Narawida, T.; Agustin, R.D.; Oktaviani, D.; Hidayat, M.B. Analisis RAPFISH Pada Studi Keberlanjutan Pembangunan Kawasan Wisata Heritage Kajoetangan Di Kota Malang. *Brawijaya J. Soc. Sci.* **2023**, *2*, 119–120. [CrossRef]
70. Pitcher, T.J.; Preikshot, D. RAPFISH: A Rapid Appraisal Technique to Evaluate the Sustainability Status of ®sheries. *Fish. Res.* **2001**, *49*, 255–270. [CrossRef]
71. Nugroho, H.Y.S.H.; Sallata, M.K.; Allo, M.K.; Wahyuningrum, N.; Supangat, A.B.; Setiawan, O.; Njurumana, G.N.; Isnan, W.; Auliyani, D.; Ansari, F.; et al. Incorporating Traditional Knowledge into Science-Based Sociotechnical Measures in Upper Watershed Management: Theoretical Framework, Existing Practices and the Way Forward. *Sustainability* **2023**, *15*, 3502. [CrossRef]
72. Langbein, W.; Iseri, K. *Manual of Hydrology: Part 1. General Surface-Water Techniques. General Introduction and Hydrologic Definitions*; Geological Survey Water Supply Paper 1541-A; United States Goverment Printing Office: Washington, DC, USA, 1960.
73. Dingman, S. *Physical Hydrology*; Prentice Hall: Upper Saddle River, NJ, USA, 2002.
74. Brutsaert, W. *Hydrology: An Introduction*; Cambridge University Press: New York, NY, USA, 2005.
75. Mosley, M.; McKerchar, A. Streamflow. In *Handbook of Hydrology*; McGraw-Hill: New York, NY, USA, 1993.
76. Winter, T.C. The Role of Ground Water in Generating Streamflow in Headwater Areas and in Maintaining Base Flow. *J. Am. Water Resour. Assoc.* **2007**, *43*, 15–25. [CrossRef]
77. Winter, T.C.; Harvey, J.W.; Franke, O.L.; Alley, W.M. *Ground Water and Surface Water: A Single Resource*; Diane Publishing: Collingdale, PA, USA, 1998.
78. Rains, M.C.; Mount, J.F. Origin of Shallow Ground Water in an Alluvial Aquifer as Determined by Isotopic and Chemical Procedures. *Groundwater* **2002**, *40*, 552–563. [CrossRef]
79. Rains, M.C.; Fogg, G.E.; Harter, T.; Dahlgren, R.A.; Williamson, R.J. The Role of Perched Aquifers in Hydrological Connectivity and Biogeochemical Processes in Vernal Pool Landscapes, Central Valley, California. *Hydrol. Process.* **2006**, *20*, 1157–1175. [CrossRef]
80. Farber, S.C.; Costanza, R.; Wilson, M.A. Economic and Ecological Concepts for Valuing Ecosystem Services. *Ecol. Econ.* **2002**, *41*, 375–392. [CrossRef]

81. Dudgeon, D.; Arthington, A.H.; Gessner, M.O.; Kawabata, Z.-I.; Knowler, D.J.; Lévêque, C.; Naiman, R.J.; Prieur-Richard, A.-H.; Soto, D.; Stiassny, M.L.J.; et al. Freshwater Biodiversity: Importance, Threats, Status and Conservation Challenges. *Biol. Rev.* **2006**, *81*, 163. [CrossRef] [PubMed]
82. Tzanakakis, V.; Angelakis, A.; Paranychianakis, N.; Dialynas, Y.; Tchobanoglous, G. Challenges and Opportunities for Sustainable Management of Water Resources in the Island of Crete, Greece. *Water* **2020**, *12*, 1538. [CrossRef]
83. Qiao, R.; Li, H.; Han, H. Spatio-Temporal Coupling Coordination Analysis between Urbanization and Water Resource Carrying Capacity of the Provinces in the Yellow River Basin, China. *Water* **2021**, *13*, 376. [CrossRef]
84. Alves, M.A.B.; De Souza, A.P.; De Almeida, F.T.; Hoshide, A.K.; Araújo, H.B.; Da Silva, A.F.; De Carvalho, D.F. Effects of Land Use and Cropping on Soil Erosion in Agricultural Frontier Areas in the Cerrado-Amazon Ecotone, Brazil, Using a Rainfall Simulator Experiment. *Sustainability* **2023**, *15*, 4954. [CrossRef]
85. De Almeida, W.S.; Panachuki, E.; De Oliveira, P.T.S.; Da Silva Menezes, R.; Sobrinho, T.A.; De Carvalho, D.F. Effect of Soil Tillage and Vegetal Cover on Soil Water Infiltration. *Soil Tillage Res.* **2018**, *175*, 130–138. [CrossRef]
86. Cantalice, J.R.B.; Nunes, E.O.S.; Cavalcante, D.M.; Barbosa, B.; Barros Junior, G.; Guerra, S.M.S.; Rolim Neto, F.C. Vegetative-Hydraulic Parameters Generated by Agricultural Crops for Laminar Flows under a Semi-Arid Environment of Pernambuco, Brazil. *Ecol. Indic.* **2019**, *106*, 105496. [CrossRef]
87. Sone, J.S.; Oliveira, P.T.S.; Euclides, V.P.B.; Montagner, D.B.; De Araujo, A.R.; Zamboni, P.A.P.; Vieira, N.O.M.; Carvalho, G.A.; Sobrinho, T.A. Effects of Nitrogen Fertilisation and Stocking Rates on Soil Erosion and Water Infiltration in a Brazilian Cerrado Farm. *Agric. Ecosyst. Environ.* **2020**, *304*, 107159. [CrossRef]
88. Borrelli, P.; Robinson, D.A.; Fleischer, L.R.; Lugato, E.; Ballabio, C.; Alewell, C.; Meusburger, K.; Modugno, S.; Schütt, B.; Ferro, V.; et al. An Assessment of the Global Impact of 21st Century Land Use Change on Soil Erosion. *Nat. Commun.* **2017**, *8*, 2013. [CrossRef]
89. Karr, J.R. Ecological Integrity and Ecological Health Are Not the Same Thing. In *Engineering within Ecological Constraints*; National Academies Press: Washington, DC, USA, 1996; pp. 97–110, ISBN 978-0-309-05198-9.
90. Bertol, I.; Schick, J.; Bandeira, D.H.; Paz-Ferreiro, J.; Vázquez, E.V. Multifractal and Joint Multifractal Analysis of Water and Soil Losses from Erosion Plots: A Case Study under Subtropical Conditions in Santa Catarina Highlands, Brazil. *Geoderma* **2017**, *287*, 116–125. [CrossRef]
91. Antoneli, V.; Lenatorvicz, H.H.; Bednarz, J.A.; Pulido-Fernández, M.; Brevik, E.C.; Cerdà, A.; Rodrigo-Comino, J. Rainfall and Land Management Effects on Erosion and Soil Properties in Traditional Brazilian Tobacco Plantations. *Hydrol. Sci. J.* **2018**, *63*, 1008–1019. [CrossRef]
92. Panachuki, E.; Aparecida, D.N.D.S.; Dorly, S.P.T.A.; Rafael, M. Soil and Water Loss in Ultisol of the Cerrado-Pantanal Ecotone under Different Management Systems. *Afr. J. Agric. Res.* **2015**, *10*, 926–932. [CrossRef]
93. Mitchell, B.C. *Integrated Water Management: International Experiences and Perspectives*; Belhaven Press: London, UK, 1990.
94. Nijkamp, P.; Vreeker, R. Sustainability Assessment of Development Scenarios: Methodology and Application to Thailand. *Ecol. Econ.* **2000**, *33*, 7–27. [CrossRef]
95. Department of Economic and Social Affairs, Division for Sustainable Development United Nations. *Report on the Aggregation of Indicators for Sustainable Development/Prepared by the Division for Sustainable Development*; Background paper (UN. Commission on Sustainable Development); United Nations: New York, NY, USA, 2001.
96. Tanguay, G.A.; Rajaonson, J.; Lefebvre, J.-F.; Lanoie, P. Measuring the Sustainability of Cities: An Analysis of the Use of Local Indicators. *Ecol. Indic.* **2010**, *10*, 407–418. [CrossRef]
97. Shen, L.-Y.; Jorge Ochoa, J.; Shah, M.N.; Zhang, X. The Application of Urban Sustainability Indicators–A Comparison between Various Practices. *Habitat Int.* **2011**, *35*, 17–29. [CrossRef]
98. The Ministry of Environment and Forestry. *Permen P.60/ Menhut-II/ 2014 ttg Kriteria Penetapam Klasifikasi Penentuan Pengelolaan Daerah Aliran Sungai (DAS)*; Ministry of Environmental and Forestry: Bogor, Indonesia, 2014.
99. Boggia, A.; Massei, G.; Pace, E.; Rocchi, L.; Paolotti, L.; Attard, M. Spatial Multicriteria Analysis for Sustainability Assessment: A New Model for Decision Making. *Land Use Policy* **2018**, *71*, 281–292. [CrossRef]
100. The Ministry of Home Affairs. *Permendagri 7/2018 Tentang Pembuatan dan Pelaksanaan KLHS*; Ministry of Environmental and Forestry: Bogor, Indonesia, 2018.
101. Nogués, S.; González-González, E.; Cordera, R. Planning Regional Sustainability: An Index-Based Framework to Assess Spatial Plans. Application to the Region of Cantabria (Spain). *J. Clean. Prod.* **2019**, *225*, 510–523. [CrossRef]
102. OECD. *OECD Green Growth Policy Review of Indonesia 2019*; OECD Environmental Performance Reviews; OECD: Paris, France, 2019; ISBN 978-92-64-42594-1.
103. European Commission, Joint Research Centre. *Regional Indicators for the Sustainable Development Goals: An Analysis Based on the Cases of the Basque Country, Navarre and Flanders*; Publications Office: Luxembourg, 2021; ISBN 92-76-38416-2.
104. Pravitasari, A.E.; Rustiadi, E.; Mulya, S.P.; Fuadina, L.N. Developing Regional Sustainability Index as a New Approach for Evaluating Sustainability Performance in Indonesia. *Environ. Ecol. Res.* **2018**, *6*, 157–168. [CrossRef]
105. Hély, V.; Antoni, J.-P. Combining Indicators for Decision Making in Planning Issues: A Theoretical Approach to Perform Sustainability Assessment. *Sustain. Cities Soc.* **2019**, *44*, 844–854. [CrossRef]
106. Central Statistics Agency. *Wonogiri Regency in Figures*; Central Statistics Agency-Wonogiri Regency: Wonogiri, Indonesia, 2022.

107. Central Statistics Agency. *Village Potential Data in Wonogiri Regency*; Village potential data in Wonogiri Regency in 2007, 2019, 2021; Central Statistics Agency: Jakarta, Indonesia, 2022.
108. Regional Disaster Management Agency. *Final Report of Preparation of Disaster Risk Maps*; Regional Disaster Management Agency: Wonogiri, Indonesia, 2016.
109. National Agency for Disaster Management. *Indonesian Disaster Vulnerability Index*; National Agency for Disaster Management: Jakarta, Indonesia, 2013.
110. Central Statistics Agency. *Wonogiri Regency GRDP Document 2015-2019*; Central Statistics Agency-Wonogiri Regency: Wonogiri, Indonesia, 2020.