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Review

Implementation of Soil and Water Conservation in Indonesia and Its Impacts on Biodiversity, Hydrology, Soil Erosion and Microclimate

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Abstract: Soil and water are natural resources that support the life of various creatures on Earth, including humans. The main problem, so far, is that both resources can be easily damaged or degraded by human-induced drivers. The threat of damage or degradation is increasing due to rapid human population growth and humans' insatiable daily necessities. Indonesia has had various experiences in soil and water conservation (SWC) programmes for a long time, which can be a good lesson learned for future strategy development. This article aims to provide an overview of the benefits of implementing SWC in Indonesia for biodiversity, hydrology, soil erosion, and microclimate to support sustainable ecological landscape management. Various vegetative and mechanical techniques that have been known and implemented can be utilized to improve future SWC strategies. It is expected that proper strategy development in the future for SWC in Indonesia will support the sustainability of ecological landscape management. Forthcoming SWC programmes are also expected to incorporate local knowledge into their implementation. The programmes also require coordination between stakeholders, i.e., local communities, management authorities, policymakers, and scientists, and seamless integration between varying fields and levels of governance. The main findings of this study are that SWC increased the adaptation of native plants to local rainfall and soil conditions; SWC increased infiltration and improved soil hydrological characteristics; and SWC, through vegetation techniques, played a role in lowering temperatures, increasing humidity, and reducing intensity levels.

Keywords: biodiversity; hydrology; landscape ecology; microclimate; soil and water conservation

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1. Introduction

Soil and water are essential natural resources that support life on Earth, including plants, animals, and humans. Unfortunately, the depletion of both resources in many developing countries is becoming a significant concern due to various factors, especially human-induced pressures on natural resources [1]. As the population continues to grow, the demand for food, water, and energy increases, leading to the overuse and depletion of land resources [2]. The utilization of natural resources beyond their carrying capacity has caused serious environmental problems in many countries. The visible impacts can result in various issues such as erosion, sedimentation of water bodies, flooding, and water scarcity [3,4].

Water supply in Indonesia fluctuates with the seasons, and its distribution varies from region to region. Generally, most parts of Indonesia have annual rainfalls of about 2000 to 3500 mm (60%). A few areas (3%) have annual rainfalls higher than 5000 mm, while others have less than 1000 mm per year. These rainfall data indicate that Indonesia, with its humid tropical climate, enjoys a natural abundance in the form of heavy rainfalls, despite occasional water shortages or droughts in some areas. Indonesia has a total territory area of 1.9 million square kilometres and an average annual rainfall of 2700 mm. Of this volume, on average, only 278 mm (10%) infiltrates and percolates through the soil as groundwater. The remainder (the larger part) flows as runoff or surface water (1832 mm). If groundwater and surface water can be managed properly, they will be available in a total volume of about 2100 mm per year, equivalent to an irrigation water flow of about 127,775 m^3/s. Total water storage capacity by land area in Indonesia is about 13.75 million hectares, including reservoirs (1.777 million hectares or 13%), dams and reservoirs (50,000 hectares or 0.4%), rivers (2.895 million hectares or 21%), and wetlands (9 million hectares or 65%) [5]. So far, the quality of those water resources in Indonesia depends on the role and efforts of soil and water conservation (SWC).

The Indonesia archipelago possesses numerous unique ecosystems due to its position in the tropical wet and humid climate with high temperatures. Additionally, it is also located in the ring of fire, causing most of its areas to be affected by active volcanoes which give rise to varying land contours. There are three major terrain types in Indonesia: (1) steeply dissected, hilly, and mountainous land covering 35 to 40% of the total land areas; (2) level to undulating areas that cover 30 to 35% of the total land mass; and (3) the coastal alluvial and peatlands that cover 30% of the rest of the land.

Rocks and minerals weathering is considerably high in Indonesia, due to the natural high rainfall and high temperature in this country [6]. Consequently, the erosion rate in the country is incredibly high, ranging from 97.5 to 423.6 tonnes/ha/year [7]. In such conditions, the community develops various soil and water conservation techniques that are very site-specific, physical, biological, and social institutions. The positive impacts of applying soil and water conservation techniques are reducing surface run off and erosion; losing nutrient elements; maintaining nutrient cycles and the existence of the subsoil; keeping cycle water; and maintaining the carbon cycle. These conditions will have a positive impact on plant growth [8]. Therefore, the nutrient cycle, water cycle, and carbon cycle are maintained and this condition will aid in mitigating climate change.

As a tropical archipelagic country, Indonesia has a relatively high amount and high intensity of rainfall, mountainous topography, and various soil types sensitive to erosion. These characteristics make the country prone to soil erosion hazards and accompanying environmental degradation. The degradation is also driven by a high population density, especially on Java Island, where most of the population works in the agricultural sector. The narrowing of agricultural land due to land conversion has encouraged farmers to continue to use and open new agricultural land in sloping areas with a high risk of soil erosion [9]. Unsurprisingly, agricultural land is Indonesia's biggest contributor to soil erosion, reaching 423.6 tons ha^{-1} $year^{-1}$ [10]. Prolonged soil erosion not only destroys land and water resources but will also further threaten the sustainability of agricultural crop production and the welfare of farmers, as well as cause other disasters [11].

This problem is overcome by preventing and mitigating land degradation by reducing the rate of soil erosion and promoting water conservation, also known as SWC [12]. SWC programmes are essential components of sustainable ecological landscape management. This is because soil erosion and water runoff can significantly impact the environment in terms of, among other things, loss of soil fertility, decrease in water quantity and quality, and degradation of natural habitats [13–15].

In Indonesia, SWC activities were first implemented in 1967 after a big flooding event in Solo City, Central Java. In the early 1980s, integrated SWC began to be implemented based on the President's instructions by handling 22 priority watersheds. The results of an analysis of forty years of SWC implementation in Indonesia highlight that the already-carried-out SWC activities have yet to be able to keep up with the expansion of degraded land and demand for environmental resources [6]. The latest mapping in 2018 shows that the area of degraded land in Indonesia still reaches 14 million hectares, or 7.5% of the total area [16]. Through the Ministry of Environment and Forestry (MoEF) coordination, the government annually carries out land rehabilitation activities, including SWC activities, and encourages the active participation of the community in implementing SWC. Unfortunately, the active involvement of the community in the implementation of SWC is still very limited, partly due to the lack of public knowledge of the importance and benefits of SWC implementation [17,18]. Only a little information about the role and benefits of SWC implementation in Indonesia has been collected and evaluated. Therefore, this article aims to provide an overview of the benefits of implementing SWC in Indonesia to support sustainable ecological landscape management. The hypothesis used in this study is that SWC can increase biodiversity, improve hydrological functions, reduce erosion, and improve the microclimate. In the viewpoint of globalization, this review is essential due to natural forest degradation and has an impact on the ecological environment, poses a threat to water supplies, and reduces biodiversity. Even the world's population has grown, impacting climate change and affecting the hydrological cycle, particularly rainfall. As a result, more floods and droughts have had a substantial negative influence on the availability of soil and water resources. Soil and water conservation aid in sustainable development.

2. Soil and Water Conservation Programmes in Indonesia: Past, Present, and Future

SWC is an outdated issue, but soil and water conservation problems have persisted due to the lack of awareness and attention from many stakeholders. It is important to restate that ever since soil and water were identified as non-renewable natural resources globally [19], SWC has become a national priority concern to support the objective of the Sustainable Development Goals. SWC refers to the management and protection of soil and water resources to prevent erosion and degradation, improve soil health and fertility, maintain water availability and quality, and keep ecosystem services functioning appropriately in supporting all living organisms on Earth. By their very nature, soil and water are souls that resemble sovereignty to all nations, including Indonesia, which attained its independence in 1945. As a result, the government and its people instinctively put a high value on conserving the spirit of soil and water to nurture the people and country as a never-ending endeavour. In a broader sense, SWC is assumed to refer to all activities at the local level which maintain or improve the productive capacity of a given landscape, including soil, water, and plants, in regions inclined to illicit deprivation through prevention of or reduction in soil erosion, soil compaction, soil toxicity, soil drought, water scarcity, and other detrimental soil circumstances, like soil acidity, pollution, and infertility.

Since SWC was considered a fundamental aspect of the economic and environmental sustainability of all types of farming and forestry systems, Indonesian people under the Dutch administration period started a plantation programme between the 16th and 19th centuries. The plantation programmes were evinced by Styrax (incense) and rubber tree plantations in Sumatra Island, and a sizeable teak forest plantation in Java Island. The entire tree plantations on numerous islands during those periods were established by implementing an ancient farming system known as Taungya. Besides forest regeneration purposes, the concomitant objective of this programme was to conserve soil and water to improve and maintain good forest hydrological conditions [20]. It is quite fascinating to note that sometime during that period, research related to SWC had also begun, as indicated by the establishment of the Laboratorium tot Vermeerdering de Kennis van den Bodem (Laboratory for the Expansion of Soil Science) in 1905 [21]. One of the most monumental accomplishments was land mapping on Java Island, especially for agricultural and plantation purposes [9].

After Indonesia's independence, SWC activities focused more on revegetating degraded land through the Karang Kitri programme. However, the programme did not run well because, at that time, the country was in a revolutionary period to keep defending its independence and faced agitation for a political power change in the mid-1960s [20].

Due to the severe flood that occurred in Solo in 1966, the SWC programme back then was directed at rehabilitating upland (upstream) areas in Java. This catastrophe was perceived as a result of severe deforestation and inappropriate agricultural practices in the area [22]. Afterwards, during the 1970s and 1980s, the government launched several donations supported by FAO to develop the SWC programmes designed to keep strengthening the watershed management projects along Solo River, Brantas River, and Citanduy River [23]. In addition, the Governor of West Java in 1970, Solihin G. Purwanegara, initiated a massive tree-planting movement to rehabilitate forest areas and teak plantations on community lands called Gandrung Tatangkalan (Rakgantang). During this period, the forest area was still relatively good. However, there was a rising awareness of erosion risk in mountainous areas due to the prevalent forestland clearing for agricultural plantations in Java back then. During these years, the government-owned company managing forest resources in Java, PERHUTANI, collaborated with local farmers to launch an agroforestry programme in their concession area [24]. The local farmers established a Community Agency for Forest Resources Management known as Lembaga Masyarakat Pengelola Sumber Daya Hutan (LMPSDH) to secure mutual advantages from the programme as a company.

The agroforestry system was initially conducted in Malang, East Java, when the company began to plant pine trees for wood supplies. During the early period, farmers planted corn, coffee, and cassava in plant line spaces until the fifth year of establishment. This system was sustained for a long time by carefully selecting the combination of crop plants and tree species that would benefit the community economically and reduce soil erosion and sedimentation in agroforestry areas [25,26].

In the 1980s, Indonesia's government and the US-ASEAN Watershed Management Project called UPSA (Natural Resources Conservation Effort) developed a big programme covering three main fields in the land use system: agricultural, animal husbandry, and fishery sectors. The programme was directed to more than just SWC; it was also set to support better agricultural production to achieve food self-sufficiency in the country. The dam construction in Kedungombo has been one of the well-known relics in Central Java until today.

In 1983, the Directorate General of Forestry, originally under the auspices of the Ministry of Agriculture, moved apart and formed the new Ministry of Forestry. In 1984, the new Ministry of Forestry developed a watershed protection programme in 22 priority areas [27,28]. As part of the reforestation and revegetation efforts in these areas, a list of fast-growing tree species was compiled for use in the programme. SWC technical activities were also implemented in production forests with the obligation to rehabilitate forest areas with low potential and plant TPN (temporary log yard) and TPK (permanent log yard) areas [29]. Basically, SWC efforts can be carried out through vegetation (land and forest rehabilitation) and mechanical (terracing system agriculture and the construction of ponds or reservoirs) systems [30,31]. During the 2015–2021 period, a realization of forest rehabilitation activities and the land reached an area of 1.26 million ha, with details per year presented in Table 1 [32].

Table 1. Forest and land rehabilitation achievements in 2015–2021 [32].

Year	Area (ha)	Cumulative Area (ha)
2015	200,452	200,452
2016	198,346	398,797
2017	200,990	599,776
2018	188,630	787,603
2019	395,169	995,253
2020	112,419	1,108,226
2021	151,073	1,259,299

Another benchmark regarding progressive changes in SWC was in the 1990s when Indonesia joined the International Soil–Water Conservation Organization (ISCO). The organization was designated to advocate for the sustainable, productive, and efficient use of soil and water resources globally. Since then, SWC practically turned into an integral part of watershed management in Indonesia under the administration of the Ministry of

Forestry. Although watershed management was formerly considered nearly synonymous with SWC, it goes far beyond it today, comprising a variety of further activities that attempt to improve the living conditions of the people existing within the respective watershed area (e.g., building social infrastructures such as schools) [33].

After the fall of the New Order regime, the National Movement for Forest and Land Rehabilitation (GNRHL) was launched in 2003 with a target of planting 3,000,000 ha over five years of activities [20]. Even though it did not achieve its target, the movement became the pillar of forest and land area rehabilitation activities on a large scale, along with various community involvements. The rehabilitation activities were focused on degraded forest areas with low or bare-standing stocks. Furthermore, to increase community participation in rehabilitation programmes, the National Tree Planting Day and the One Man One Tree movement were launched in 2008 and 2009, respectively [9].

Along with technological and industrial development, various mechanical techniques are used to reduce environmental degradation due to land degradation during and after industrial activities. The construction of water reservoirs around community settlements also helps control water flow and reduce the danger of flooding [34].

Reduced-impact logging in the forestry industry is an effort to protect ecosystem functions through the conservation of soil and water by minimizing soil damages caused by heavy equipment and selection of tree stands for timber harvesting based on the trees' diameters and their positions on sloping land and distance to a watershed zone [35]. The application of a pulling pile machine system, while log skidding on sloping or rather steep land, can reduce soil exposure compared to using a bulldozer skidding technique [36].

In response to the climate change issue, a method of harvesting timber with the reduced-impact logging system has also developed with adaptations to the less-emission harvesting system without reducing timber yield productivity [37]. This technique is known as reduced-impact logging for climate change mitigation (RIL-C), designed to implement sustainable forest harvesting methods as a climate change mitigation strategy and an option as a voluntary carbon market [37–39].

Nowadays, national concerns about SWC have been reviewed to develop several substantial strategies:

1. Integration, coordination, and supervision related to SWC between stakeholders are essential. In this case, strong political will is needed.
2. Current disasters are actually a reflection that these resources are not properly conserved. Therefore, there is a need for watershed management that is integrated with the upstream–downstream mechanism so that when there is damage in the upstream area, as well as in the downstream area, the consequences of damages are addressed in both upstream and downstream areas.
3. Institutions and policies related to SWC should be fully implemented. Additionally, existing technologies must be implemented in the field accordingly.
4. Upstream watersheds must be conserved because currently they are widely used for tourism and settlement purposes.
5. Community participation through agroforestry or social forestry systems should be enhanced to widen the programme's scope and impact.

All those important concerns are already framed under the Soil Conservation Act number 37 of 2014, and the Indonesian government puts forward many related programmes to achieve the country's sustainable development goals in terms of protecting and promoting the sustainable use of terrestrial ecosystems on soil, water, and vegetation.

3. Soil and Water Conservation and Its Impacts on Biodiversity

Indonesia is one of the seventeen global megadiverse countries, with two out of the twenty-five biodiversity hotspots in the world [40]. However, the rate of primary forest loss in Indonesia is double that of the Democratic Republic of the Congo and triple that of Brazil [41]. The drivers of forest loss in Indonesia range vastly from the industrial-scale logging of montane rainforests to the small-scale destruction of coastal peatlands. The loss of forest cover that human-induced factors have caused impacts Indonesia's biodiversity at various levels. Although the type of forest loss varies widely across the landscape, the continued exploitation of primary tropical rainforests remains the most prevalent type of forest loss in Indonesia [41].

In order to address long-term concerns in biodiversity conservation, Indonesia must strike a balance between protection and sustainable utilization to its national biodiversity. Thus, SWC becomes a crucial component of the environmental sustainability of forestry systems [42]. SWC's favourable impact on vegetation cover, plant diversity, richness, and restoration is logical [43]. On the other hand, vegetation has been an essential component in the watershed ecosystem, providing a buffer element for soil erosion and drought [44] and increasing soil's capacity to hold water [45]. The diversity of tree species in upstream watersheds, such as *Alstonia scholaris*, *Arenga pinnata*, *Artocarpus heterophyllus*, and the commonly dominant species *Pinus merkusii*, has essential roles in maintaining soil conservation and forest ecosystems in general [46]. Likewise, *Coffea arabica*, an important crop and vital product in several highland countries, contributes significantly to water conservation [47]. Other species that can be cultivated for vegetative SWC are *Tectona grandis*, *Delonix regia*, *Switenia mahagoni*, *Cassia siamea*, and *Samanea saman* [48]. Tree-level vegetation has various characteristics that can affect surrounding environmental conditions.

Additionally, the establishment of understorey plants that have the potential to maintain SWC in the upstream area is urgently needed. A previous study proved that *Mimosa pudica*, *Ageratum conyzoides*, and various other understorey plants possess a high potential for conserving soil in watershed areas [44]. The functions of ecosystems' soil conservation can be improved through vegetation restoration, which can also successfully lessen soil erosion [49]. Grassy vegetation covers can hold the surface runoff and increase water infiltration into the soil [50]. The presence of vegetation will positively impact the ecosystem's balance on a broader scale in a complex landscape system (Figure 1) [51].

Figure 1. Key components related to SWC in the ecosystem management.

In other words, the presence of forest vegetation and its litter layers may reduce the amount of surface runoff and convert rainwater into groundwater supply [52]. Such a condition is vital in maintaining soil stability and reducing soil loss in steep slopes [53]. Knowing that each vegetation type has its respective role and understanding the potential of runoff suppression plants and their role in supporting SWC are crucial. As important resources, soil and water can be preserved by utilizing native plants adapted to local rainfall and soil conditions. Local communities believe that native plant species have the ability to maintain the existence of natural springs and preserve the soil. To ensure better management and utilization of natural resources, local communities are expected to be able to collaborate with local and national governments [54].

4. Soil and Water Conservation and Its Impacts on Hydrology and Soil Erosion

Massive development and population growth have caused land use changes that affect the hydrological response of a watershed [55]. In a watershed management plan, reduced hydrological function due to land degradation is the main target for rehabilitation [56]. A degraded watershed is characterized by minimal base flow during the dry season, high direct runoff during the rainy season, erosion, and sedimentation exceeding the threshold. Continuous erosion will excessively shed essential nutrients and organic matter on the soil surface and can inhibit the soil's physical, biological, and chemical functions. This condition will also reduce the hydrological properties of the soil due to minimal soil organic matter content and is accompanied by a decrease in aggregate stability and water-holding capacity [57].

4.1. Impact on Runoff

In Indonesia, most watershed degradation has been caused by changes in land cover. It is accompanied by an increase in runoff, especially in the upstream region, initially in the form of forest cover [58]. Deforestation and forest degradation can affect forest hydrological function. This function is essential for managing water, regulating the microclimate, and mitigating disaster [59].

Afforestation on a wide scale can suppress erosion and runoff, but attention must be paid to determining the composition and species used, especially in dry climates. The selected species have ecological consequences. Therefore, it is important to consider the climate conditions, soil hydrological characteristics, and landscape forms. Improper species determination results in water shortages and exacerbates land degradation [60]. Previous research on soil's hydrological properties reported differences in the effects of three tree species [59]. *Pinus merkusii* had a more significant effect on fluctuations in soil water content (3.1%) compared to *Hopea odorata* (2.4%) and *Khaya anthotheca* (1.9%). For the infiltration variable, *P. merkusii*, *H. odorata* and *K. anthotheca* had values of 95.5, 27.9, and 28.6 cm/hour, respectively, while their permeability values were 9.2, 8.1, and 8.7, respectively.

Improvement in the hydrological function of a watershed through SWC can be carried out on the principle of reducing slope and slope length. Constructive or vegetative measures can also increase infiltration and improve soil hydrological characteristics [61,62]. Improvement in the hydrological quality of a watershed is characterized by a decrease in the flow regime coefficient (FRC), i.e., the ratio of maximum discharge to minimum discharge; a reduction in the annual flow coefficient (AFC), i.e., the balance between runoff and rainfall amount in a year; a reduction in direct runoff; and increases in base flow and water yield [63]. At Ciliman Watershed (Banten Province), the application of SWC reduced FRC, AFC, and direct runoff by 31.6%, 24%, and 23.6%, respectively, and increased base flow and water yield by 16.2% and 1.8%, respectively [64]. The application of SWC at upper Cimanuk Watershed (West Java) reduced the flow regime coefficient, reduced runoff by 40.8%, and increased lateral flow by 536.9 mm [65]. At the upper Opak Watershed, the application of SWC was able to reduce runoff by 27.1%, increase base flow by 18.3%, and improve FRC and AFC values [56]; meanwhile, at the upper Cisadane Watershed, SWC reduced runoff [58].

The choice of an SWC technique should be adjusted to local characteristics such as the amount of rainfall, slope, soil type, and crop species. The difference in these characteristics affects the effectiveness in suppressing runoff, which averages 13–71%. In 2014, the National Standardization Agency of Indonesia released the Indonesian National Standard (SNI) 7943:2014 about soil and water conservation guidance for addressing degraded land. The SNI document stated that successful indicators for soil and water conservation are tolerable erosion value and runoff coefficient according to the soil type, land use, and management. Runoff coefficients are presented in Table 2 [66].

Table 2. Successful indicator for soil and water conservation according to the tolerable runoff coefficient.

No.	Cover Crop; Hydrology Condition	Runoff Coefficient for Rainfall Rate		
		25 mm/h	100 mm/h	200 mm/h
1.	Plants in rows; bad	0.63	0.65	0.66
2.	Plants in rows; good	0.47	0.56	0.62
3.	Paddy; bad	0.38	0.38	0.38
4.	Paddy; good	0.18	0.21	0.22
5.	Grass, crop rotation; good	0.29	0.36	0.39
6.	Grass, steady development; good	0.02	0.17	0.23
7.	Forest; good	0.02	0.10	0.15

Dunes accompanied by silt pits, bench terraces, tied ridges, and mulch can reduce runoff by 51–57%, while rock mounds can suppress it by 50–86%. By applying grass strips and hedgerows, runoff can be reduced by 56 and 61%, respectively, even up to 77%, depending on the plant species and density [57].

In oil palm plantations, the application of bunds can reduce surface runoff by 63.4%. Its effectiveness is proven to be higher through a combination with the *Nephrolepis biserrata* cover crop, with a runoff reduction of 95.7% [67]. Cover crops can also be effectively combined with sediment traps and manures to reduce runoff by 127.8 m^3/ha [68].

Organic materials derived from plant parts and animal waste, known as mulch, are potent in SWC. Apart from being a soil nutrient enhancer, it is also related to the presence of and increase in soil macrofauna activities which can improve soil structure, stability, and porosity and accelerate decomposition [69]. The presence of mulch and soil macrofauna significantly reduces runoff and increases soil moisture [70]. Mulch has also been effective in suppressing evaporation and creating a more comfortable growing place for plants [71,72]. The SWC technique is applied during reforestation using *Khaya anthotheca.* It involves vertical mulching at 6 m intervals, which effectively reduces runoff by 75%, or 12 m intervals, which reduces runoff by 41% [31]. The application of mulch combined with ridge furrow has been shown to increase water use efficiency and crop yields [73], including in areas that often lack water [74]. The combination of the two SWC techniques is proven to increase soil water content to a depth of 50 cm, maintain soil water storage to a depth of 110 cm, and increase the growth and production of crops [72].

Soil "bunds" effectiveness is influenced by the distance between bunds. The narrow spacing between bunds effectively accommodates surface runoff in the bund channels and increases the infiltration rate of surface runoff water. Observations for two years on a slope of 9%, with a distance between ridges of 5 m, found a reduction in runoff to 53%, 2.2 times lower than controls [61].

SWC's ability to suppress runoff is also followed by increased soil moisture. The combination of contour ridges and infiltration pits can maintain soil moisture within a radius of about 3 m, especially on gentle slopes, with range decreasing as the slope increases [75].

The application of soil bunds can also increase soil moisture (soil water content). Soil water content increases as the distance between the ridges (i.e., the slope distance) decreases. It is due to the increasing infiltration in the soil medium between bunds since mounds can reduce the speed of water flow and delay runoff. To find the optimal spacing of soil bunds in each region requires exploring the effect of bund spacing on different landscape biophysical aspects, economic feasibility, and social acceptability [61].

Rainfall intensity and slope conditions influence the amount of surface runoff. Observations on the watershed scale show that SWC in contour ridges and hillside reservoirs that is applied to 21% of the watershed area can reduce runoff by 41–50%, especially if the rainfall intensity is 40 mm/event [76]. On average, contour ridges that are applied to 43% of the catchment area can suppress 50–80% of runoff. If the rainfall event is below 70 mm, the SWC used can reduce runoff by up to 95%, and if the rainfall reaches 80 mm, the runoff can be reduced by 75% [77].

On tea plantations with slopes of 8–35%, a contour trenches treatment, combined with cover crops, reduces runoff to half compared to plantations that do not apply SWC. This SWC technique also increases soil moisture from 18.6% to 25.1%. Higher soil water content can be associated with the retention of runoff in trenches, followed by absorption in the soil profile in the root zone [61]. In tropical date palm plantations, silt pits reduce surface runoff by 88.55% [78].

The occurrence of erosion changes soil characteristics. The soil becomes difficult for plants to grow, and infiltrated rainwater becomes limited compared to runoff. This condition makes water availability for plants increasingly limited, threatening food security and the environment [69,79]. Efforts to increase water availability for plants through water infiltration are carried out by suppressing evaporation and runoff. The selection of SWC techniques, water harvesting techniques (WHT), and water use efficiency can be adjusted according to local conditions. Excessive infiltration triggers landslides in areas prone to landslides; thus, surface runoff must flow through drainage channels to storage areas/reservoirs.

The use of water harvesting techniques is not only restricted to supplying water for agriculture but also reduces the amount and velocity of runoff, which causes erosion of the fertile topsoil [80]. At Cilemer Watershed (Banten Province), constructing a reservoir as an alternative to SWC reduced direct runoff by 29.2%, decreased AFC from 0.25 to 0.17, increased base flow by 46.0%, and increased water yield by 3.99% [63]. At Pesanggrahan Watershed, creating six reservoirs reduced 24.6% of peak flow, while the current conditions are only able to reduce 6.4% [81].

Applying a hedgerow barrier has the main purpose of SWC. However, hedgerow plant biomass as an auxiliary product can be used directly as food, animal feed, and firewood. Soil equipped with a hedgerow barrier can increase infiltration up to eight times compared to the surrounding area due to improved macro soil porosity from increased organic matter and root canals [82].

4.2. Impact on Soil Erosion

Indonesia's topography is dominated by sloped land, and most areas have high rainfall. With a high population with a majority of farmers, making agricultural land with ideal conditions is increasingly difficult to obtain. The expansion of agricultural land and plantation is mostly carried out in sloping areas, which are often not accompanied by SWC measures, which contributes greatly to soil erosion [9,10]. If this condition is not handled, it will lead to a decrease in land productivity and can result in more severe disasters. Appropriate SWC application not only suppresses runoff but effectively reduces erosion. One of the successful indicators for soil and water conservation can be indicated by tolerable erosion value. Tolerable erosion values, as determined by the Indonesian National Standard (SNI) 7943:2014 are presented in Table 3 [66].

In oil palm plantations, several SWC methods have been tried, such as bench terrace, individual terrace, cover crop, sediment trap, vertical mulch, and some combinations of measures. The measurement results using erosion plots show that SWC measures are more effective if they consist of two or three measure combinations. The combination of bench terrace, cover crop, and manure produces a reduction in the erosion of up to 70% compared to the control, while the other best combination is a combination of silt pit, cover crop, and manure with a reduction of up to 60% [68]. The application of silt pits has also proven to be effective in suppressing erosion in date palm plantations at Aceh Province. By implementing silt pits, erosion that occurs during extreme rainfall can be reduced by up to seven times [78].

Table 3. Successful indicator for soil and water conservation according to the tolerable erosion value.

No.	Soil Characteristics and Substratum	Tolerable Erosion Value (mm/year)
1.	Very shallow soil over rocks	0.0
2.	Very shallow soil over weathered material (unconsolidated)	0.4
3.	The shallow soil above the material has weathered	0.8
4.	Soil of medium depth above the material has weathered	1.2
5.	Deep soil with impermeable subsoil water on a weathered substrate	1.4
6.	Deep soil with undersoil slow permeability, on top of the substrate has weathered	1.6
7.	Deep soil with subsoil medium permeability, above the substrate has weathered	2.0
8.	Deep soil with a deep permeable subsoil, over the substrate has weathered	2.5

Remarks: Soil of deep depth (>90 cm); soil of medium depth (50–90 cm); soil of shallow depth (25–50 cm); soil of very shallow depth (<25 cm).

The application of SWC is not only effective in agricultural and plantation lands, but has also proven effective when applied to reforestation areas. The use of vertical mulching can reduce erosion by 37% at 6-m intervals, while at 12 m intervals, erosion can be reduced by 30%. A significant reduction in erosion is also accompanied by five times the prevention of nutrient loss compared to the control [31].

5. Soil and Water Conservation and Its Impacts on Microclimate

There are several SWC techniques that can be implemented, e.g., vegetative, technical, mechanical, and chemical techniques [21,83–88]. SWC through vegetation techniques plays an important role in improving microclimate quality (Figure 2). In areas with low rainfall, soil conservation techniques can maintain soil moisture or provide water in the soil [89]. Vegetation significantly affects microclimate conditions by controlling the solar radiation received by the ground. Sufficient vegetation cover can reduce the heating effect. The air temperature in vegetated areas is also more comfortable than in non-vegetated areas. This is due to the plant leaves that can intercept, reflect, absorb, and transmit solar radiation. The effectiveness of those processes depends on each plant species' characteristics. Every species has varying shapes, forms, colours, textures, and sizes. Ecologically, trees can help improve air quality by lowering the microclimate temperature and absorbing water and air pollutants [90]. In addition, trees can also absorb carbon dioxide and produce oxygen.

SWC through a vegetation technique that covers areas with tree stands may help maintain soil moisture. This SWC technique is vital for protecting dry soil types prone to high temperatures, such as sandy and gravel soils [91]. Soil conservation through vegetation techniques is also crucial in maintaining other microclimate formations. It can significantly reduce the amount of solar radiation reaching the soil, thus reducing the earth's surface and air temperature, wind speed, and increasing soil moisture and relative humidity in surrounding locations [92].

One of soil's abilities to store water, namely, soil moisture binding, controls the rate of evaporation or soil water loss. This evaporation rate can be restrained by adding organic matter to the soil [93]. By placing organic material on the soil surface, mulching reduces evaporation from the soil by cutting off water vapor transport between the soil surface and the atmosphere. Mulching can also hinder weed growth and transpiration. Previous research in Kulon Progo District, Yogyakarta Province, reported that such soil conditioning treatments changed soil thermal properties by reducing daily temperature fluctuations at 0–25 cm soil depth to 27–30 °C and reducing evaporation by 55–90% of relative air humidity [93]. Compared with tillage, mulching has significant advantages in maintaining soil moisture [94], reducing water losses due to soil evaporation, and thus improving crop yields [95–97].

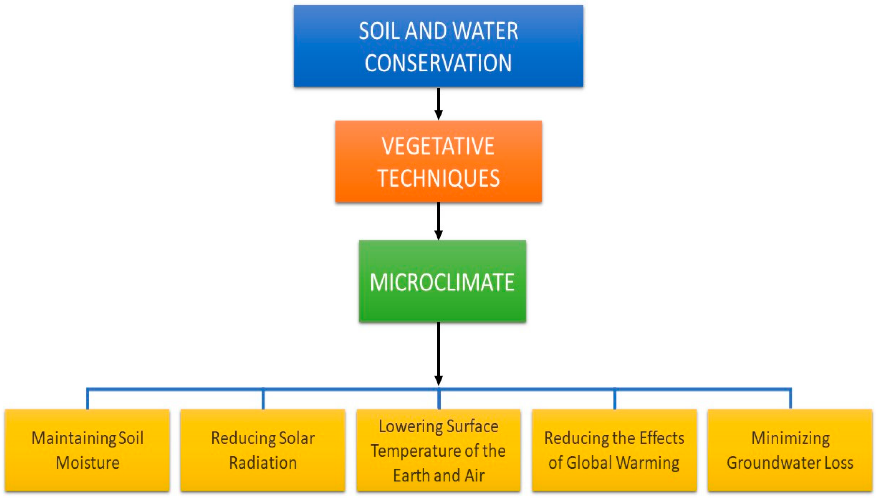

Figure 2. SWC through vegetation techniques plays an important role in improving microclimate quality.

SWC activities in Indonesia have provided many benefits for microclimate improvement, especially for cooler ambient temperatures. Examples of these can be found in villages that successfully carried out SWC efforts through critical land rehabilitation, namely, Rancasalak Village in Garut Regency, Karangsari Village in Ciamis Regency, Selopamioro Village in Bantul Regency, and Kertowono Village in Lumajang Regency [98]. Several previous studies in Indonesia highlight that SWC, through vegetation techniques, may provide vegetation succession that plays a role in lowering temperatures, increasing humidity, and reducing intensity levels [89,92,93]. SWC through the agroforestry model also improves the microclimate, especially regarding climate buffering, and reduces climate variability [26,99].

6. The Way Forward

Human activity in using and modifying environmental resources can threaten humans [100]. As an example, industrial and urban development contributes to environmental degradation, including decreased SWC quality [101,102]. Climate-related issues have exacerbated various environmental problems, from food security to the degradation of nature and wildlife that affect human life [103,104]. Advancements in SWC management should aim to improve soil and environmental quality to sustain life [39]. Identifying and understanding critical problems in degraded lands is pivotal for the success of the SWC programmes planned by policymakers [100]. Further, evaluating the programmes' implementation is critical to understanding the contributing factors to the successes or failures of the implemented SWC [105].

SWC methods have been critical tools for restoring degraded land and preventing further harm to terrestrial resources. They have served as useful tools for local communities to protect their environment and improve land productivity by reducing soil erosion and increasing soil fertility, particularly in cultivated fields [106]. SWC implementation at both the technical and policy levels requires proactive participation from stakeholders at large [107,108]. Government policies must align with and adopt some of the results of existing research and involve researchers in the policy-making process. Furthermore, the success of an ecosystem service model depends on multidisciplinary teams. Future research should concentrate on creating multidisciplinary thinking and working processes. Straightforward programmes and targets will guide practitioners and officers to assess the management application in their activities. Good delivery of programme goals and technical aspects will be crucial to the future SWC management. The programme's scope based on the habitat, soil condition, or landscape area is essential [109], especially for complex ecosystem types and functions in Indonesia. As an archipelagic country, Indonesia has five main islands and thousands of small islands with varying slopes, ecosystems, and land use conditions. Each type of scope has a distinctive management of SWC systems that suit it the best, based on empirical and best practices. Integrated upstream and downstream area management should have equal concerns in the practice and conceptualization of the programme.

Although regulations on soil conservation have been in place since the 1970s, SWC research had not been conducted until the turn of the 20th century. The SWC procedures in Indonesia have yet to be entirely successful. This issue is partly due to insufficient resources and overlooking scientific evidence in the process of making SWC regulations [9]. Meanwhile, in Indonesia, SWC existed long before the government's SWC regulations were established. It is reflected in the involvement of local communities in conserving water and land through their customary rules. Thus, incorporating social and cultural aspects is essential for the success of SWC programmes in Indonesia [25,110].

Several cultures have also been known for implementing SWC through sustainability in land use management, farming system, soil treatment, and revegetation methods [9]. For instance, several indigenous tribes have established relatively similar sacred forest land use, but in different local names, which is actually quite similar to the modern protected forest system. This traditional knowledge system towards conserving the water catchment area has positively impacted the presence of natural springs [111]. Forest preservation through sustainable management and selection of endangered species that are originally from the sacred forest [112] can support SWC with traditional knowledge. The selection of *Jatropha curcas* through agroforestry techniques strongly supports the success of SWC [113]. Harmonizing SWC with community culture can increase the success of its implementation and application. Including different generations in SWC implementation and campaign might also benefit the programme more. Furthermore, when both engineering (terracing, slope hydraulics project, and gully control techniques) and biological techniques (afforestation, hedgerow, and enclosure) are applied together, soil and water loss can be reduced more successfully. However, the adoption of these strategies will be greatly limited by financial factors, technological knowledge, and details on the technical parameters [114].

The legislative and policy basis of an SWC programme should be well prepared for its success. There has been an option to empower the programme with a legal policy focusing on SWC management in any industrial or practical land use aspect. For many years, the programme's legal aspect has been separated into different fields, i.e., agricultural, forestry, urban and rural development, and industrial policies, with different aspects of soil and water assessment [23]. Most of these policies were formulated by different government institutions that consolidated and coordinated weakly. Solid political will is also essential to ensure the policies' establishment. It can only be achieved through in-depth discussions and efficient information exchanges between people, management authorities, and scientists.

An SWC programme should also reflect long-term impact and application with adaptation options to climate issues. The improvement in environmental qualities through SWC implementation will ensure the improvement in soil and land for food security and wildlife well-being in nature, which further enhance the sustainability of environmental management in Indonesia [115]. The success can be invoked by hard work and cooperation among all stakeholders, including all communities and government sectors related to land use and the environment, especially in SWC.

7. Conclusions

Many lessons have been learned about the role of SWC in Indonesia so far, which can set an example at the global level. Changes in various SWC efforts were adjusted to various regulatory changes and the dynamics in the existing communities. The role of community participation, consistent implementation of SWC regulations, and the government's political will in SWC implementation are critical to support sustainable development goals in Indonesia. The Indonesian government had many related programmes to achieve the country's sustainable development goals in terms of protecting and promoting the sustainable use of terrestrial ecosystems on soil, water, and vegetation. Harmonizing SWC with community cultures can increase the success of its implementation and application. The inclusion of multiple generations in the SWC implementations and campaigns might also benefit the programme even more. Furthermore, when both engineering (terracing, slope hydraulics project, and gully control techniques) and biological (afforestation, hedgerow, and enclosure) techniques are applied together, soil and water loss can be reduced more successfully.

So far, many long-term benefits have been achieved through the SWC implementation in Indonesia, including biodiversity, hydrology, and microclimate benefits. SWC increased the adaptation of native plants to local rainfall and soil conditions, which impacted biodiversity. SWC increased infiltration and improved soil hydrological characteristics that had an impact on soil and hydrology sustainability. The selection of SWC techniques related to water harvesting techniques and water use efficiency can be adjusted according to local conditions. SWC through vegetation techniques also played a role in lowering temperatures, increasing humidity, and reducing intensity levels that had an impact on the good quality of the microclimate. The applicability of SWC in this review can be implemented in the region condition with a tropical wet, humid climate, and most of the areas are dominated by sloping areas with three major terrains: steeply dissected, hilly, and mountainous land.

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