The Potential of Agroforestry to Overcome Agricultural Land Degradation in the Dieng Plateau, Central Java, Indonesia

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Abstract.

Most of the Dieng Plateau area in Central Java, Indonesia, is a stretch of agricultural land in the upper watershed whose sustainability is threatened. The degradation of agricultural land, which affects the surrounding area and the area beneath it, is an old problem that still needs to be resolved. Agroforestry has been promoted as a sustainable land management system with various benefits and advantages. However, data and information regarding its potential to overcome the degradation of agricultural land in the highlands still need to be provided. Our integrative review found that the benefits and advantages of agroforestry to reduce erosion rates and increase land fertility have the most potential to overcome the various impacts of agricultural land degradation in the Dieng Plateau. Adopting agroforestry deserves to be one of the main strategies to overcome the degradation of agricultural land in the highlands, not only in the Dieng Plateau but also in other highlands worldwide.

1. Introduction

The Dieng Plateau is a stretch of land with an altitude of 1,300 to 2,500 m.a.s.l., which is administratively located in 6 (six) districts in Central Java and is upstream of 8 (eight) watersheds. The central Dieng Plateau in Banjarnegara and Wonosobo districts is the second highest plateau after Nepal, rich in geological potential, Hindu temple heritage tourism, and the agricultural sector. The horticulture-based agricultural sector, especially potato crops, is still the economy's source for most land-owned farmers in Dieng. It contributed more than 58% to Central Java's total potato production, which reached 269,476 thousand tonnes/year.

Potato plants that have entered intensively and been introduced by farmers from Pangalengan, West Java, since 1985 have contributed significantly to improving the farmer's economy, modernizing agriculture, and modernizing equipment and technology.
Income contribution from potato farming reaches 69.70% of the total income of farmer households [10,11].

Figure 1. Administrative Map and Watershed Boundaries of the Dieng Plateau (Source: Modification of [1])

On the other hand, Dieng's inheritance of land management is hereditary [12,13]. The narrow area of land ownership ranges from 0.2–0.3 ha per HH [2,9]. The technique of planting and making potato beds in the direction of the slope, even on sloping land, is a common practice carried out by most potato farmers in Dieng [14]. In addition, potato cultivation is also carried out openly without mulch [15]. The potato cropping pattern is 2–3 harvests without crop rotation [16], and the application of chicken manure is still very large, reaching 15–20 tons/hectare [17]. The use of pesticides and drugs on a large scale is still the primary strategy to maintain the productivity of potato plants, especially during the rainy season when the volume of use will increase [6].

Intensive monoculture cultivation without regard to conservation that has long been practiced has led to the degradation of agricultural land in Dieng Plateau [9,14,18,19]. It causes erosion rates reaching 121,434–166,350 t/ha/year [20,21], and causing various negative impacts that are not only local around the area but also to the areas below it [22,23].

Just like in Dieng Plateau, currently, the majority of highlands in Indonesia, most of their agricultural land is in a degraded condition [24–28]. One of the recommendations raised to overcome various problems due to the degradation of agricultural land is through the Landscape Approach [29–31], including through Agroforestry [32–34]. Agroforestry is one of the main strategies for implementing U.N./SDGs in all world production landscapes, including agricultural landscapes [33].

Agroforestry is a simple definition but is complex in practice [35–37]. Conceptually, agroforestry is a collective name for land-use systems and technologies in which woody perennials (trees, fruits, shrubs, palms, grass, or bamboo) are intentionally planted on the same land management unit simultaneously or sequentially to be enhanced, diversified, and maintained with other crops, Agriculture or animals, both in spatial form and in the same time sequence [37–39].

Agroforestry has various advantages and benefits and should have the potential to overcome various problems of agricultural land degradation in Dieng Plateau. Nevertheless, data and information related to this are limited. Therefore, this study aims to identify the...
various advantages and benefits of agroforestry and the various impacts of agricultural land degradation that have occurred in Dieng and to analyze the potential of agroforestry to address agricultural land degradation in the Dieng Plateau.

2. Materials and methods

This study uses two review approaches. The first is a narrative review of the various benefits and advantages of agroforestry originating from the Scopus-indexed journal database for 2013–2021, which are considered relevant for study and review. Researchers widely use narrative reviews to identify literature, summarize existing literature, provide comprehensive reports on current research conditions, and selectively focus on available evidence related to a topic [40]. There are approximately 29 articles relating to the benefits and advantages of Agroforestry as a result of studies which will then be analyzed more deeply.

The second is a systematic review conducted to analyze the various impacts of agricultural land degradation in the Dieng Plateau through a review of various articles from Google Scholar for the 2013–2021 period. We use a broad search strategy to ensure that relevant articles to the objective can be accommodated [41]. In the first step, an electronic search for articles using the terms in Bahasa and English likely “Degradasi lahan” Or “Impact” OR “Dampak” AND “Dieng” only yielded two reference articles. Finally, the researcher decided and replaced the keyword with only “Dieng” so that 679 articles were produced. To exclude inappropriate articles, we expand the search using the term Dieng-(“panas bumi”) OR (geothermal) OR (“culture festival”) OR (ruwatan) OR (hutan) OR (wisata) OR (pariwisata) OR (budaya) OR (kebudayaan) OR (rambut gimbal) OR (rambut gembel) OR (kebudayaan) OR (ritual) OR (candi) OR (kesenian) OR (pendidikan) OR (kunjungan) OR (forest) OR (geologi) OR (perjalanan) OR (Travel) OR (hotels) OR (geology) OR (tourism) OR (kesehatan)), so we can found 277 articles. We also removed 136 citations that only cite other articles. Furthermore, from 268 articles, there were 190 articles whose titles did not fit the purpose, so the remaining 78 articles. Then after reviewing and scanning the abstracts and contents of the articles, there were 17 articles left for us to analyze further.

After an in-depth analysis of the previously selected articles, we classified various agroforestry potentials and the impacts of land degradation in the Dieng plateau. In the end, a qualitative analysis to determine the potential and relevance of various agroforestry benefits to overcome land degradation was conducted by comparing the two. The first researcher and the third researcher also coded the relevance/appropriate level scale. Then the results were examined further by the second author until a mutual agreement was reached.

3. Results

3.1. Impact of Dieng Plateau Agricultural Land Degradation

The Dieng Plateau is upstream of many watersheds, and even though the mismatch of land use with the Spatial and Regional Planning (RTRW) is only 9.36% of the total area, in reality, these conditions have affected environmental conditions not only having local and regional impacts [23]. The potato cropping pattern of 2–3 harvests without crop rotation and fallow/rest periods in a year which many potato farmers apply, significantly reduces potato productivity compared to the cropping pattern which only harvests one time a year [16]. In addition, the increase in the frost phenomenon has resulted in crop failure and losses of up to hundreds of millions of rupiah [42].
Excessive use of insecticides and fungicides coupled with high soil erosion has affected the quality of soil fertility and biodiversity in agricultural land in Dieng. Microorganism carbon biomass (C\text{mix}) content of potato farms around the tourist sites was 748.03 µg.g/1, having much higher fertility than fertility in potato fields on hillsides prone to erosion, only having C\text{mix} content of 305.14 µg.g/1. The diversity index of macrofauna on the surface of the soil was higher than that of macrofauna in the soil, with the diversity index in shaded areas/forests also higher than in exposed areas/potato gardens ranging from 0.62 to 1.04. Open agricultural land without mulch also causes the Soil Biological Quality Index (QBSar) value, which is a method for measuring soil fertility based on the presence of microarthropods, on potato farms using plastic/shaded mulch ranging from 76-77, much higher than agricultural land without plastic mulch both on flat and sloping land which only ranges from 43-70. The critical role of soil fertility and porosity in reducing surface erosion can also be observed from the rainwater infiltration process in Dieng. The infiltration rate on potato farms is 340 mm/hour, much higher than farms that apply agroforestry patterns, which are only 254 mm/hour. The impact of damage to agricultural land can also be seen from water contamination in residents' wells or lakes in the Dieng area. The analysis of healthy water and Sewiwi Lake water samples conducted in Kepakisan Village, one of the main villages in Dieng Plateau, showed NO3 and COD levels higher than the water quality standards. In well water samples and water samples, the average COD was 16.8 mg/L and 12.60 mg/l higher than the water quality standard, which was only 10 mg/l, NO3 (Nitrate) levels were 13.5 mg/l, and 30.15 mg/l is also higher than the water quality standard of 10 mg/l. The use of high doses of nitrogen fertilizers significantly increased nitrate concentration in river water by 64% and 68% higher than nitrate in river water in the upper reaches of the Klakah river at Dieng. Nitrate concentrations ranged from 24.00-40.97 mg/L during the dry season and 6.91-17.88 mg nitrate-NO3/L during the rainy season. Both were higher than the allowable nitrate (NO3) levels for drinking water, namely 10 mg/L. The volcanic lakes in the upstream area of Dieng Plateau cannot be separated from the impact of intensive potato cultivation. Merdada Lake is threatened with eutrophication and siltation, while Cebong Lake, although threatened with siltation and shrinkage, is in better condition due to increased awareness to protect the lake. Likewise, Telaga Warna lake, a study using diatom sediment records 24 cm from the top of the core in the 2014–2016 period, shows that human activities (deforestation and potato farming) in the catchment area have changed the oligotrophic acid of the Telaga Warna lake to become eutrophic/more acidic. Fertile is characterized by high levels of nitrogen, phosphorus, cadmium, and lead, which are higher than water quality standards, and changes in organisms/algae in the form of changes in diatoms from Frustulia spp. to Seminulum grunow.
3.2. Benefit and Advantages of Agroforestry

Adoption of agroforestry on agricultural land can increase agricultural productivity and farmer income compared to monocultures [50–54]. In upland Vietnam, the combined productivity of longan, maize, and the grass are higher than maize monoculture, which, even after seven years, has resulted in 2–5 times the higher average annual income [55]. Adopting agroforestry on agricultural land can improve household food safety and security [56–58].

The existence of fruit and wood plants that are applied to the agroforestry pattern of cultivators on Mount Salak, Indonesia, is a food safety net that can be sold at any time or can be a substitute for food during difficult and vulnerable periods due to crop failure, long dry seasons or the presence of farmers or family members sick cultivators [59].

Agroforestry practices improve soil and water fertility and quality through increased organic matter, more diverse microbial populations, and better nutrient cycles [60]. Soil fertility on agricultural land due to the use of agroforestry patterns is indicated by the presence of decomposing microbes in the soil [61], the presence of microbial carbon biomass/Soil Organic Carbon [62] and the presence of mycorrhizal fungi [63] which form colonies of fertile roots with shade plants. Agroforestry practices for 20–30 years can significantly improve agricultural soil’s microbiological and chemical conditions compared to traditional agriculture [64]. The application of nitrogen-fixing crops/use of fertilizer trees/legumes in Agroforestry also contributes to increasing soil fertility through nitrogen fixation by increasing the supply of nutrients for production [56,65].

In order to deal with market and seasonal uncertainties, clove farmers in the eastern coastal region of Madagascar combined their crops with vanilla and diversified tree species. They diversified the use of its undersoil for various crops. The agroforestry system is also regulated according to the age of the clove trees to cope with fluctuations in world clove prices [66].

Reducing the concentration of carbon in the atmosphere through the process of absorption through plants or soil, as well as combining the potential to increase soil biomass and carbon storage (C) while maintaining agricultural production is an essential function of agroforestry systems concerning climate change adaptation and mitigation [67,68]. Carbon stocks in agroforestry can be found in soil organic/biomass on the soil surface and carbon stocks in the soil. Regarding changes in land use, the most significant above-soil carbon absorption of 12.8 t C ha/year occurred when better fallows replaced degraded land, and the most significant soil carbon absorption of 4.38 t C ha/year occurred during the system transition from pasture to the silvopastoral system [69].

Agroforestry is also proven to reduce the rate of water erosion and can be a way of handling and rehabilitating critical lands. The existence of trees with deep roots, as well as the leaves and litter they produce, can reduce water precipitation and water infiltration as well as retain water and soil in agricultural landscapes [44,70]. Agroforestry patterns also protect and utilize water through the role of shade/canopy from the structure and composition of the stands [71–73]. It can even affect the microclimate in a region [74].

Increasing tree species diversity can reduce pest and disease risks compared to monoculture systems or growing only a few tree species in the landscape [75]. On a landscape scale, increased tree cover in forest areas converted to tea plantations contributes to maintaining 93% of the plant pollinators. That can be found in natural forests and reduces the adverse effects of an increased abundance of white stem borers and ladybugs, which can result in reductions of up to 60% of tree species compared to the reductions gained from natural forests [76]. The abundance of mammals, pollinating insects, and ground ants was higher in shaded coffee agroforests than in coffee agroforests without shade [77,78].

Increasing tree species diversity can improve habitat health by reducing pest and disease risk compared to growing only a few tree species across an agricultural landscape [76,79].
The presence of shade plants in agroforestry patterns can reduce the quality of coffee bor
er attacks and will be significant if the level of shade cover ranges from 11–34%, with an
optimal rate of 25% and inhibits the spread of coffee fungus spores.

3.3. The Potential of Agroforestry to Overcome Land Degradation

After the review was carried out, we then classified the various types of advantages and
benefits of agroforestry into 8 (eight) types, as well as the various impacts of land degradation
into 8 (eight) types of impacts. Henceforth, we made a simple comparison of the types of
advantages and benefits of agroforestry one by one with the types of agricultural land
degradation impacts to estimate the potential of agroforestry. Of course, technical
considerations based on our knowledge and various literature studies form the basis for our
considerations in determi
ning the agroforestry potential which is the results can be seen in
Table 1.

Table 1. Results of comparative analysis of agroforestry potential

<table>
<thead>
<tr>
<th>Benefits and advantages of agroforestry</th>
<th>Impact of Agricultural Land Degradation at Dieng Plateau</th>
<th>Relevance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Increasing land productivity and farmer income [50–55,82]</td>
<td>Decreased soil fertility [15,19]</td>
<td>3++, 7++, 8++</td>
</tr>
<tr>
<td>2. Improve food safety [56–59,83]</td>
<td>Decreased yield/productivity [7,16,42]</td>
<td>1+++, 3++</td>
</tr>
<tr>
<td>4. Overcome market and season uncertainties [66]</td>
<td>Local flood and landslide disaster potential [48,84,85]</td>
<td>6++</td>
</tr>
<tr>
<td>5. Increasing carbon stocks/Climate change adaptation [67–69]</td>
<td>River and water pollution in residents’ wells [45,46]</td>
<td>6 +++, 3+</td>
</tr>
<tr>
<td>6. Reduce the rate of erosion, sedimentation [44,70–74]</td>
<td>Silting of reservoirs/lakes in the lower region [22,49].</td>
<td>6 +++</td>
</tr>
<tr>
<td>8. Improves habitat health [75,76,79–81]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

We made a simple comparison by conducting a qualitative analysis one by one between
the types of advantages and benefits of agroforestry with the type of land degradation impact
of Sarapatu by using code numbers and symbols to facilitate understanding of interpretation.
In the relevance column, the numbers 1–8 in front of the + (Plus) symbol indicate the serial,
number of benefits and advantages. In contrast, the symbols (+) are less intense, (++) moderate, and (+++) are used to indicate the level of relevance/appropriateness is very powerful/strong (See Table 1). The serial number pair of agroforestry benefits and advantages and the level of relevance will represent the agroforestry potential. For example, the symbol (1++) on the right side of the impact of land degradation in the form of a decrease in yield/productivity can mean that the benefits of agroforestry serial number 1 (one), namely the benefits and advantages of increasing land productivity and farmers' income, have strong relevance for addressing the impact of land degradation in the form of decreased yields/productivity at Dieng Plateau if agroforestry was adopted.

Agroforestry benefits and advantages number 3 (three), namely to increase soil fertility, has not only strong relevance to addressing the degradation of agricultural land in the form of decreased soil fertility but also has moderate relevance for addressing the impacts of land degradation in the form of nitrate pollution/eutrophication in surrounding ponds, pollution residents' rivers and wells, and a decrease in the diversity of soil fauna. Whereas the benefits and advantages of agroforestry number 6 (six), namely to reduce erosion and sedimentation rates, have strong relevance for addressing the impacts of land degradation in the form of nitrate pollution/eutrophication in lakes/ponds, potential local flood disasters, river and water pollution in community wells, silting of reservoirs/lakes in the lower areas, and silting and shrinking of the lake in the catchment area. Meanwhile, the benefits and advantages of agroforestry number 7 (seven), namely to maintain and increase biodiversity, has strong relevance for overcoming the impacts of land degradation in the form of decreased soil fertility and decreased soil fauna biodiversity. The benefits and advantages of agroforestry number 8 (eight) to improve habitat health have strong relevance for addressing the impacts of land degradation in the form of decreased soil fertility and decreased soil fauna biodiversity.

4. Discussion

Benefits and advantages of agroforestry to increase land productivity have great potential to directly overcome the impact of agricultural land degradation on Dieng in the form of a decrease in yield/productivity. Combining seasonal crops with trees, fruits, and forage for livestock can improve food security and increase land productivity and farmers' income [52,56,59]. In the trial plots in the Vietnamese highlands, after 3-4 years, when the longan trees started to bear fruit, the income from longan, maize, and grass agroforestry was much higher than monocropping cultivation (maize monoculture), even after seven years, it had yielded 2-5 times higher average annual income from monoculture maize cultivation [55].

Meanwhile, it relates to the ability of agroforestry to increase land fertility. Loss of vegetation cover is a cause of loss of soil fertility due to erosion [90] and shows the phenomenon of supply and export of fertilizers and pesticides to drainage systems/rivers and other bodies of water [46,90,91]. On a landscape scale, the absence of shade trees on coffee plantations if they are clear-cut, will cause the loss of earthworm populations and can reduce macro porosity by up to 76% lower, thereby reducing soil fertility [76]. Agroforestry can improve soil fertility by improving soil microbiology and is chemically better than monoculture farming [64,92,93]. In addition, nitrogen fixation by fertilizer trees in various agroforestry patterns also significantly increases soil fertility by increasing the supply of nutrients for crop production [56,65].

Regarding the benefits and advantages of agroforestry to reduce erosion and sedimentation rates, it can be explained as follows. Trees, their roots, composition, and structure of leaves that form the canopy and the litter they produce in the Agroforestry pattern can play a role in protecting and utilizing water and reducing erosion rates through their role in reducing water precipitation, water infiltration, and water retention, and soil retention. In the study, the role of trees in reducing erosion was observed through the decrease in the amount of soil lost from the plot and the increase in the amount of soil retained in the plot. The increase in the amount of litter produced by trees also played a role in reducing erosion through the increase in the amount of organic matter in the soil, which acts as a binder for the soil particles.
Agricultural land in the water catchment area to a forest will reduce the yield of sediment entering the river by around 10%, even a 10% change from agricultural land to the forest is estimated to have the potential to reduce the yield of sediment entering the river by up to 50%. Changes in the type and cover of vegetation in the upstream area will affect soil texture, soil organic matter, available phosphorus, carbon-to-nitrogen ratio, cation exchange capacity, percentage of base saturation, and exchangeable bases and have the potential to cause problems. In downstream areas, such as sediment deposition and erosion on agricultural land. Land cover in the upper reaches of the Cimanuk watershed is ideally 30% in forest vegetation. However, only 19% is in the form of forest and exacerbated by dryland farming, with a majority of vegetable crops, and 42% with a cropping pattern that pays attention to conservation has caused flash floods in Garut Indonesia 2016. At the landscape scale, an increase or change in vegetation cover will not only affect land fertility but will also affect the abundance of biodiversity. In shaded coffee agroforestry, an abundance of up to 28 morphotypes of mycorrhizal fungi were found, while in coffee agroforestry without shade, very little was found. In coffee agroforestry land with the shade, it was also found that there were 64% more microbial communities than monocultures, more soil organic matter up to more than 10%, and more fauna and nematodes. Plant/habitat health is closely related to the presence/attack of plant pests and the reaction of plants/habitat to overcome them. The presence of shade trees in coffee agroforestry can reduce the quality of coffee borer attacks, which will decrease significantly if the level of shade cover ranges from 11-34%, with an optimal rate of 25%.

For the record, this review article has limitations that must be considered when reviewing and assessing the findings. First, this review only describes ideal conditions for how the adoption of agroforestry has the potential to overcome the problem of agricultural land degradation with a simple comparison based on our understanding of the contents of the articles that have been collected without considering the various factors and processes that influence farmers' decisions to adopt agroforestry is very complex. Secondly, in terms of the location being reviewed, Dieng Plateau is very broad. However, in this review, the articles on the impact of degradation are primarily the result of studies conducted by various researchers on potato-based agricultural land in the main Dieng area and focus only on environmental and economic aspects. So the amount of literature and topics that can be obtained is limited, on the other hand, the literature used for a review of the various benefits and advantages of agroforestry comes from all over the world, so of course, the data is more numerous and more complete. The positive side is that the limitations of this review provide wider opportunities for researchers to study or review agroforestry adoption and the impacts of land degradation that have not been covered in this study more broadly and in more depth.

5. Conclusion

The results of the review that has been carried out, there are 8 (eight) benefits and advantages of agroforestry and 8 (eight) impacts of agricultural land degradation that occur in the Dieng Plateau. It can also be known from 8 (eight) types of land degradation impacts that exist in Dieng Plateau, all of them have relevance and potential to be resolved by various benefits and benefits and advantages of agroforestry. Likewise, especially in Dieng Plateau, the impact of land degradation on social aspects is interesting to study because previous studies have mainly discussed or focused on the environmental aspect. In addition, it is also known that the benefits of agroforestry to reduce erosion rates and increase land fertility are the most potential benefits for overcoming various impacts of agricultural land degradation in Dieng, 0300 E3S Web of Conferences 448, 03034 (2023) ICENIS 2023 https://doi.org/10.1051/e3sconf/202344803034 34 (2023)
Plateau. In the end, it can be concluded that adopting agroforestry on agricultural land, with its various benefits and advantages that have been proven empirically, has tremendous potential and strong relevance and can be used as one of the main strategies by the government, researchers, and other related parties for overcoming various impacts of land degradation not only on Dieng Plateau but also for other highlands in various parts of the world.

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