Biodiversity-based ecosystem services for the management of monoculture plantation landscape using a transdisciplinary approach: a review

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Abstract. Doubling of the global population in the next 30 years will increase demand on the land and water resources that are in relatively fixed supply. Agriculture intensification will continue to be the main choice in the future. Intensified land use in agriculture is irrefutably the main reason for biodiversity-based ecosystem service loss. In Indonesia, the current area of agriculture land is approximately 40 million ha (21% of total land). Monoculture system is the most adopted practices in the agriculture landscape. Therefore, there is a need to develop an agricultural landscape that supports biodiversity-based ecosystem services. There is an observed linkage between biodiversity and ecosystem service in a tropical agricultural landscape. Redesigning agricultural landscapes for biodiversity-based ecosystem services is not a straightforward undertaking, especially in the developing country like Indonesia where many people already inhabit the agriculture landscape. There are so many socio-economic and policy aspects involved in its real implementation. It requires much effort to reach an agreement for appropriate landscape design that suits all socio-economic setting. We need to move beyond the scientific formalities to dialogue with farmers and other private and public agencies about the advantages and drawbacks of landscape design. We need the so-called transdisciplinary approach involving close collaboration with policymakers and all stakeholders to develop landscape-scale research into the agricultural landscape design.

1. Introduction
Agricultural land use occupies a relatively large proportion of terrestrial area, so management of biodiversity and related ecosystem services in an agricultural landscape is very important. Agriculture intensification is irrefutably the main reason of global biodiversity loss [1,2]. It has been confirmed that the monoculture system accompanied by intensive use of pesticide and fertilizer has a negative impact on biodiversity [3]. In Indonesia, the current area of agriculture land (includes paddy rice, horticulture, oil palm plantation) is 40 million ha (21% of total land). The area of oil palm plantation in Indonesia in 2017 is about 14 million ha [4]. Monoculture system is the most adopted practices in the agriculture landscape. Therefore, the improvement of biodiversity in agricultural land is very important.

Biodiversity is the different variety of plant and animal life in the world, including their genetic diversity and the variety of species and ecosystems. Ecosystem diversity consists of different habitats such as tropical forests, agriculture area, wetlands, rivers [5]. Biodiversity can be differentiated in three different levels, namely a) genetic diversity at crop level, b) farm and field level, and c) landscape level.
Due to the higher productivity target, agriculture intensification has been practiced in most places. The agricultural intensification often associated with the intensive application of pesticide and inorganic fertilizer. Use of excessive inorganic fertilizer can reduce the richness and the abundance of soil microorganism. The pesticide can reduce pollinator population, which is very important for sustainable production. Therefore, the use of intensive pesticide and fertilizer together with monoculture system reduce agriculture biodiversity. In a big plantation, besides using high chemical inputs, it also uses heavy mechanical types of machinery triggering soil compaction. This agricultural intensification without taking into consideration its impact on the biodiversity can cause loss of various ecosystem services such as nutrient cycling, pollinator biodiversity, and water flow regulation. The rapid advancement of science and technology in agriculture should consider the role of agriculture in protecting biodiversity, storing carbon, regulating water, and preserving pollinators and other important ecosystem services.

In the last decade, there is a change in biodiversity conservation policies from primarily focused on species and ecosystem conservation to the restoration of ecosystem services [6]. According to the Millennium Ecosystem Assessment [7], ecosystem services are defined as the benefits people obtain from ecosystems. Some researchers had explored the linkage between biodiversity and the ecosystem services, but the nature of those relations still needs to be closely examined and formulated [8,9,10]. Beside its linkage to the ecosystem services, the biodiversity could also strengthen the resilience capabilities of ecosystems to provide the service in the shadow of future climate change [11].

Despite the growing research interest for biodiversity-based ecosystem service linkages, the connections between these aspects still need further research. The notion that biodiversity significantly influences the ecosystem has gained much support from theoretical and experimental model systems [12], but there is still a lack of example in the real landscape [19].

The linking of environmental issues to the ecosystem services can gain more attention from the decision-maker due to its linkage to the human benefit. To be able to plan and to prioritize interventions, evaluate the progress of achievement towards targets, and to make it accountable, the ecosystem services need indicators [13]. According to [13], Ecosystem services can be classified as follow (Table 1)
Table 1. Ecosystem services classification with a focus on agricultural landscape, adapted from [13].

| Ecosystem services | Category | Definition | Example |
|--------------------|----------|------------|---------|
| **Provision**      | Food (Crops) | Agriculture products harvested by people for human or animal consumption as food | Maize, rice, groundnut, banana |
|                    | Livestock | Animals raised for domestic or commercial consumption or use | Cattle, chicken, goat |
|                    | Biological raw materials | Tree products from natural forest ecosystems, plantations, or non-forested lands | Palm oil, rubber, pulp and paper |
|                    | Biomass fuel | Biological material that serves as a source of energy | Fuelwood |
|                    | Natural medicines, and pharmaceuticals | Medicine plants from ecosystems for commercial or domestic use | Ginger, turmeric |
|                    | Freshwater | Inland surface water, groundwater, rainwater for household, industrial, and agricultural uses | Water for domestic use, cattle, and irrigation |
| **Regulating**     | Climate regulation (regional and local) | Influence ecosystems have on local or regional temperature, precipitation, and other climatic factors | Forests can impact regional rainfall levels |
|                    | Water regulation | Influence ecosystems have on the timing and magnitude of water runoff, flooding, and aquifer recharge, particularly in terms of the water storage potential of the ecosystem or landscape | Some organisms create permeable soil facilitates high infiltration rate and groundwater recharge, decrease flooding |
|                    | Erosion regulation | Vegetative cover retains soil | Vegetation such as grass and trees prevents soil loss, riparian |
|                    | Soil quality regulation | Role ecosystems play in sustaining soil’s biological activity, storing and recycling nutrients and gases | Some organisms aid in the decomposition of organic matter, increasing soil nutrient levels |
|                    | Pest regulation | Influence ecosystems have on the prevalence of crop and livestock pests and diseases | Predators from nearby forests – such as bats, toads, and snakes – consume crop pests |
|                    | Pollination | Role ecosystems play in transferring pollen from male to female flower parts | Bees from nearby forests pollinate crops |
| **Cultural services** | Recreation and ecotourism | Recreational pleasure people derive from natural or cultivated ecosystems | Hiking, camping, and bird watching• Going on safari |
| **Supporting services** | Nutrient cycling | The flow of nutrients (e.g., nitrogen, carbon) through ecosystems | Transfer of nitrogen from plants to soil |
|                     | Water cycling | The flow of water through ecosystems in its solid, liquid, or gaseous forms | Transfer of water from the soil to plants, plants to air, and air to rain |

2. Biodiversity and ecosystem services

There are some strong pieces of evidence that the agricultural intensification had affected various ecosystem services due to the loss of biodiversity. Decreasing population of pollinator population due to the loss of appropriate habitat is a good example. The same crop but with different varieties can show different flowering stages necessary for the continuation of pollinator’s population. Another example is soil compaction due to the reduced activity of soil microorganism.

The so-called ecological intensification has been introduced as a means of increasing the sustainability of farming by maintaining high yields through biodiversity-based ecosystem functions,
or intermediate ecosystem services [14,15]. Planting the same crops with different variety can reduce the risk of plant disease spreading [16]. At farm and field level, planting field with different crops having different rooting depth and stems high will facilitate better nutrient and energy uptake. Different crops at farm field can also prevent diseases spread. At the farm level, it is also possible to practice integrated farming of crop and livestock facilitating better nutrient cycling and reducing the dependencies of outside input [17].

The improvement of biodiversity in agricultural land is essential to maintain necessary ecosystem services [17,18]. Biodiversity guarantee nutrient and water regulation. Examples of ecosystem services relevant for agricultural landscapes are diversity that support: a) pollinators, b) biological control of pests and diseases, c) nutrient cycles d) water regulation, e) erosion control, f) sediment retention [13,19]. Ecosystem services can be used as a tool in The flow with decision-makers to trade-off competing for demands from a broad range of stakeholders for various benefits from intensive agriculture and conservation area for pollinator habitat or water recharge area potable water [20].

2.1. Biodiversity and soil-related ecosystem services

Soil functions receive little attention in policy-making as compared to water and air. The protection of soil resource is often neglected in important international reports such as Sustainable Development Goals (SDG). SDG pay relatively little attention to soil protection. Linking soil with ecosystem services may give the opportunity to include it in the decision-making process. Soil related ecosystem services supported by the biodiversity includes: a) nutrient regulation (storage and cycling) through microbe decomposition activities, b) soil water regulation through macro pore creation by soil microbe, c) soil erosion and landslide through various riparian vegetation [17, 21].

Interaction of soil organic matter and microbe activities is a major soil service in determining soil structure, nutrient cycling and water storage in the soil and [19]. Biodiversity and soil ecosystem services include complex relationships among diverse taxa from millipedes (nutrient cycling) and earthworms (soil structure, water infiltration, water-holding capacity), and springtails (organic matter decomposition), to spiders (predation) and millions of microbes in the soil [22]. Legume diversity can improve also the nitrogen-fixing ability and enhance nitrogen availability. Crop planting with a diversity of rooting depth in the soil profile can better prevent soil erosion and landslides. It also provides higher surface roughness necessary for water flow ecosystem service through the reduction of runoff volume and velocity. Reduced runoff volume and velocity contribute to erosion reduction. Some soil holds 25% of biodiversity but 33% of agricultural soils are already degraded [5]. Forest conversion to oil palm leads to considerable changes in the soil, especially soil compaction and erosion [23]. In monoculture systems like oil palm plantation and rubber, the decomposition of tree leaf litter was slower (ca. 61% less mass loss) compared with forest due to the fewer microbe activities [24].

Several biodiversity practices can be undertaken to improve soil diversity and increase related ecosystem service provision. These include minimum tillage, much application, agroforestry, intercropping and crop rotations. Agroforestry systems contribute to increase infiltration, higher surface roughness, a higher variation of rooting depth, higher canopy multistate reduces the speed of raindrop impact on the soil erosion. Cropping systems with high agricultural biodiversity show increased soil carbon by 28–112% and nitrogen by 18–58% compared to systems with less biodiversity [25]. Understorey vegetation is necessary as a source of leaf litter in plantations, which can itself support a higher diversity and abundance of taxa [26].

2.2. Water flow regulation

One important service in an agricultural landscape is water flow regulation (for example oil palm plantation which requires). Water flow regulation can increase water retention necessary for plant production. Nowadays, physical soil water conservation measures (for example silt pit) dominate the management of water flow regulation in agriculture landscape [27]. Due to some limitation in its implementation, especially the amount of labor needed to implement and to maintain alternative
measures (for example biodiversity-based services) should be considered. Biodiversity supports the water flow regulation through the following factors: a) higher surface roughness as a result of crop diversity for surface runoff reduction, b) better soil porosity due to the higher diversity of soil microorganism allowing higher infiltration, d) multi-strata canopy as a result of crop diversity for higher rainfall interception. Higher surface roughness reduces the runoff velocity allowing more time for surface water to infiltrate to the soil profile, which in turns increase groundwater recharge and reduce flooding event [27]. Higher groundwater recharge will increase water availability during the dry season and provide support for crop production. Higher diversity of soil microorganism will stimulate higher soil porosity and support for higher water infiltration and higher groundwater recharge. Multi-strata canopy in a landscape will support for a higher interception. Higher interception will reduce runoff volume necessary for flood reduction.

Component of biodiversity that regulates water flow and storage in the soil include plant cover, organic matter, and soil biological activity. The activity of earthworm, termites and other microfauna develop soil pores, meanwhile, bacteria and fungi strengthen aggregates. All these organisms and other decomposer are also responsible for synthesis and decomposition of soil organic matter. The land cover above and at surface level and surface litter regulate erosion and sediment control. Important factors regulating water flow (water infiltration and retention) are surface ground cover consisting cover crop or litter. The absence of these factors leads to higher run-off and reduced infiltration with the consequence of higher erosion. Another important factor is the diversity of organic litter is likely to have a positive effect by varying timing of litterfall and rates of decomposition from the soil surface [19]. The soil macro-fauna activity in soil between litter layer and soil profile leads to the creation of macro-pore necessary in the partitioning of rainfall between surface runoff and infiltration. The macro-pores support soil water movement to the groundwater [19].

Several biodiversity practices can be implemented to improve water flow ecosystem service. Agroforestry systems and strip cropping contribute to increasing infiltration, cover crop and litter for higher surface roughness, higher and multilayer canopy reduce the speed of raindrop impact on the soil erosion. Diversity of riparian crop planting supports water flow ecosystem services through filtering sediment, increasing infiltration, and reducing runoff velocity. Intercropping provides ecosystem services to optimizes nutrient cycling. Maintaining heterogeneity of the landscape by allocating a certain proportion of the landscape in the form of forest patches (land sparing concept) can improve ecosystem service of water flow regulation [28].

2.3. Pollinators
Pollination is one of the most important ecosystem services in agricultural production. About 94% of plants in the tropical region depend on the animal pollinators [29]. Land use transformation from forest to monoculture agriculture had been indicated as a major factor for decreasing pollinator population. Several studies showed that habitat transformation has decreased pollinator species [30,31] Preserving pollinator habitat is an important key to ensure the diversity function of pollinators.

At the earlier days in South East Asia, oil palm pollination depended on a single species of Elaeidobius kamerunicus which was introduced into the area from its native West Africa in the early 1980s [32]. A high abundance of local pollinator species can support adequate oil palm pollination [33]. High numbers of non-Elaeidobius kamerunicus were found on oil palm near the forest, it was not definitive if they were useful for pollination [34]. Obviously, there is a possibility of a higher diversity of oil palm pollinators than is generally known,

2.4. Pest and disease control
Using pest-resistant crops and crop combinations and rotations, agricultural biodiversity support plant protection through ‘natural pest control’ and strengthening natural enemies, [35]. Mosaic landscapes such as fallows, field margins, riparian and forest patches, intermixed with intercropping, lead to larger natural enemy populations (by up to 74%) and lower landscape pest pressure (by up to 45%)
than simpler landscapes [36]. In addition, it can reduce damage by pests dispersed by wind, by disrupting their movement between fields in the agricultural landscape [37].

Integrated pest management techniques are now commonly practiced in oil palm plantation including the use of the fungus Metarhizium anisopliae to control of rhinoceros beetles, Heteroptera to control herbivorous insects and barn owls to fight rats [38].

3. Landscape design for biodiversity-based ecosystem services

Considering the importance of agriculture landscape for human beings, much effort should be given to explore the relationship between biodiversity and ecosystem service. Much research on this area comes from Europe, and North America, similar studies should be conducted in the South East Asia region where landscape heterogeneity has not reached the tipping point for its difficult restoration. Managing biodiversity at landscape level include appropriate area combination of cropped and non-cropped vegetation.

Non-cropped areas can range from continuous adjacent forest to smaller forest fragments remained the surrounding of oil palm landscape [39]. The non-cropped vegetation like forest patches can facilitate habitat for insect diversity, soil erosion control, water flow regulation and wildlife corridor [40, 41, 42].

The pattern of combination in the landscape can be differentiated into types, namely a) land sparing and b) land sharing. Land sparing is the intensification of farmland while at the same time conserving or freeing up permanent vegetation like forest patched for biodiversity conservation elsewhere, while land-sharing is the establishment of farmland and conserved area in the same location of the landscape by maintaining the conservation value of the farmed land itself [43,44]. Land sparing concentrates agricultural activities on the landscape most suitable for production functions in term of land and socio-economic suitability. Meanwhile, the conservation area was allocated in the area unsuitable for production functions. The land sharing concept allows the contribution of the conservation area to provide ecosystem services such as pollination and nutrient cycling. A land sparing concept is considered to be particularly suitable for the tropic landscape, where the rapid expansion of agriculture threatens forests or high conservation value areas with high biodiversity [45].

Nevertheless, a distinct separation of landscape areas allocated for agriculture production and biodiversity protection has been criticized for two reasons. First, many species for biodiversity-based ecosystem services like pollinator are found outside forested areas, also necessitates conservation strategies within production land (including both farmland and managed forests [46,47] Second, distinct separation neglect the role biodiversity-based ecosystem services within the agricultural landscape which can affect agriculture production [48].

Some researchers argue that to be effective for biodiversity conservation, land sparing must be carried out across large areas [49] while others say that land sparing can be applied successfully at relatively small spatial scales like field boundary [50]. In relation to scaling, land sparing should be considered as a strategy to be implemented simultaneously at multiple spatial scales [51]. Ecosystem services related to the nutrient cycling in the agriculture landscape is normally managed at the field scale. The ‘spared land’ in the context of land sparing can include different type of land use such as natural or near-natural habitats [49], grazed grasslands [52], more fine-grained habitat fragments [53,54], field boundaries [55]. The proportion of a landscape needs to be spared at various spatial scales and at various ecosystem services remains an open question for further research. Based on a watershed scale study in Jambi, Indonesia, the proportion of a watershed to be maintained as a forested area to ensure good ecosystem service of water flow regulation is 30% [28].

One possibility of landscape design with a land-sharing concept in oil palm plantation is an agroforestry system, which can increase the structural diversity of a monoculture oil palm [56]. Another possibility of landscape design with a land-sparing concept in monoculture oil palm is in form of tree island inside monoculture plantation with a size of the island from 50 m x 50 m up to 250 m x 250 m which is being studied in an oil palm plantation in Jambi, Indonesia [57]. Nevertheless, these landscape design still pose a question of practical application in enterprise-scale due to the possible
reduction of crop productivity and the threat of pest coming from this habitat [58, 59]. It is important to quantify the costs and benefits for each type of landscape design using the socio-economic model, for example, using agent-based modeling [60, 61].

4. Transdisciplinary approach

A different layer of society or stakeholder has a different perception of the value of biodiversity-based ecosystem services. This different perception will affect their involvement in its adoption and implementation. Four different categories can be differentiated concerning diversity values [19, 62]. First is the intrinsic value. This value arises when particular ethnicity gives high social value to certain species of a group of organism. It falls usually into cultural ecosystem services. Second is the utilitarian value of biodiversity component, these are a direct benefit for society or stakeholder. It relates to the production and consumption utilization or provision ecosystem service. It ranges from the simple utilization like the use of local herbs inside the forest as medicine plant up to the food, fiber, and plantation production. Third, is serependic value. This is the belief that particular species might have an important use in the future, but now it is still undiscovered. Fourth is the functional value of diversity. This is the contribution of the biodiversity to the preservation of ecological structure and integrity

One typical characteristic of an agricultural landscape in Indonesia is that the number of farmer household residing in a particular landscape is normally relatively high. Therefore, it requires much effort to reach an agreement for appropriate landscape design that suits all socio-economic setting of the stakeholder. In addition, the local government stakeholders related to the ecosystem restoration often reside under different legal and policy domains and management offices [63]. For example in Indonesia, cropped agriculture landscape related land-use legislation and policy are typically fall under the ministry of agricultural governance systems, while forested area related landscape is in the domain of ministry of environment and forestry. On the other hand, water flow regulation related ecosystem services fall within the domain of ministry of public work. Redesigning agricultural landscapes for biodiversity-based ecosystem services is not a straightforward undertaking. There are so many socio-economic and policy aspects involved in its real implementation. Despite the common acknowledgment of national environmental regulation related to the biodiversity conservation, it often requires support from local government regulations to implement the design of agricultural landscapes (for example in oil palm-dominated landscape) and to reduce the biodiversity loss [64].

Transforming from a monoculture system to biodiversity-based agriculture landscape to enhance ecosystem services will require a new approach of research and extension. We need to move beyond the scientific formalities to dialogue with farmers and other private and public agencies about the advantages and drawbacks of landscape design. We also need to develop a close collaboration with policymakers to develop landscape-scale research into the agricultural landscape design. Researchers collaborated with farmers to develop specific knowledge that farmers needed for designing agriculture landscape to support biodiversity-based ecosystem services [65]. Due to the missing approaches (or best practice guidelines), it is, therefore, necessary to address the topic of landscape development with a transdisciplinary reflection of landscapes [66, 67, 68, 69]. Realizing and comprehending the complexity of landscapes is an important requirement for landscape design and development. A case study in the Mondsee catchment in Austria showed that transdisciplinary approach using informal and participatory methods and the integration of local stakeholders enhances affectivity of landscape design and planning through knowledge exchange, education among participants and building trust [70].
5. Conclusion
In Indonesia, the current area of agriculture land is approximately 40 million ha (21% of total land). Monoculture system is the most adopted practices in the agriculture landscape. Therefore, there is a need to develop an agricultural landscape that supports biodiversity-based ecosystem services.

There is an observed positive linkage between biodiversity and ecosystem services in the tropical agricultural landscape [71]. For example, biodiversity and soil ecosystem services include complex relationships among diverse taxa from millipedes (nutrient cycling) and earthworms (soil structure, water infiltration, water-holding capacity), and springtails (organic matter decomposition), to spiders (predation) and millions of microbes in the soil. Biodiversity also supports the water flow regulation through the following factors: a) higher surface roughness as a result of crop diversity for surface runoff reduction, b) better soil porosity due to the higher diversity of soil microorganism allowing higher infiltration, d) multi strata canopy as a result of crop diversity for higher rainfall interception. In the case of pollinator, there is a sign that the leveling off of oil palm productivity can be related to the reduction of pollinator diversity as a result of forest loss around the plantation.

The extent of the linkage between particular species and specific ecosystem services should be further identified in more detail especially concerning the trade-off between economic and ecological aspects to be able to be considered in the decision-making process of biodiversity-based landscape design.

Transforming from a monoculture system to biodiversity-based agriculture landscape to enhance ecosystem services will require a new approach of research and extension. We need to move beyond the scientific formalities to dialogue with farmers and other private and public agencies about the advantages and drawbacks of landscape design. It is, therefore, necessary to address the topic of landscape development with a transdisciplinary reflection of landscapes.

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