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Tree species preference and land rehabilitation perspective by local community: Case study in Bondowoso, East Java, Indonesia

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Abstract. *Danarto SA, Budiharta S, Fauziah. 2019. Tree species preference and land rehabilitation perspective by local community: Case study in Bondowoso, East Java, Indonesia. Asian J For 3: 54-63.* Forest and land rehabilitation efforts require socio-economic assessment to enhance the likelihood of success when such efforts are implemented on the ground. This study aimed to find out local community's preference on tree species used for rehabilitation programs and their perspective that influence such selections in regard to social, economic and ecological objectives of land management. The study was conducted Gubrih sub-watershed, Sampean watershed in Bondowoso District, East Java, Indonesia which provided an ideal case study of land rehabilitation. Questionnaires were distributed to respondents chosen randomly to select tree species that have ecological and/or economic values. Result of the study showed that among 62 species of trees listed in the questionnaire, there were 45 species chosen by the respondents. There were 13 species of trees selected by more than 20% of total respondents (high preferred), suggesting the potential list of species for rehabilitation programs in the region. Local community in Gubrih Sub-watershed had understood the importance of trees as a source of income as well as a measure to conserve environmental functions. This was strengthened with land-use systems they selected which preferred tree-based land-use systems, such as in the form of plantation of timber species and agroforestry over dry land agriculture. The findings of this study suggested that there is opportunity in rehabilitating degraded lands in Sampean watershed using tree species preferred by local communities under the land use system of timber plantation or agroforestry. Our study demonstrates that similar strategy of incorporating ecological and socio-economic perspectives could be applied to another regional context to enhance the chance of success of rehabilitation programs.

Keywords: Land degradation, land rehabilitation, trees preferences, social-ecological systems, watershed

INTRODUCTION

Deforestation and land degradation in Indonesia, especially in Java, have been occurring since long time ago which is caused by forest clearing for agricultural activities to feed the expanding population and for developing settlements, resulting in the decreasing extent of forested areas (Nawir et al. 2007). Land conversion and exploitation from forested or tree-based vegetation into different land uses (such as agriculture, urban settlement, and industries) sometimes lack to consider soil conservation practices, causing soil degradation (Faisol and Indarto 2010). Soil degradation in the form of erosion can lead to further environmental deterioration through sedimentation, pollution and increased flooding (Morgan 2009). These conditions have been the driving force behind rehabilitation programs since the colonial eras with the main objective are to conserve soil and water.

Land rehabilitation is necessary to improve biological and habitat diversity at a landscape level, increase the productivity of land by planting trees to generate timber and non-timber products, enhance forest functions such as water storage, water balance, sequestration of carbon, climate mitigation, and restore soil fertility and physical properties for protection against erosion (Kobayashi et al. 2001). In other perspectives, land rehabilitation by tree planting can promote human well-being (i.e. economic benefits and quality of life) as described by Fisher et al. (1996). The economic benefits of rehabilitation can be in the form of additional incomes from selling timber and non-timber products, while the quality of life includes reduced heat effect, pollution reduction, fresh air and aesthetic view as the results of planting trees (Elmqvist et al. 2015; Roy et al. 2012).

Forest and land rehabilitation conducted either at a site level (i.e. small area consisting of single land management) or at a landscape scale (i.e., large area consisting of multiple land management) will affect different people in different ways. There were many cases of rehabilitation programs that failed because of the lack of involvement of local communities or ignorance of their interests when implementing the programs (Lamb and Gilmour 2003). Therefore, perception, acceptance, and participation by local communities in forest and land rehabilitation are important when designing forest rehabilitation programs to enhance feasibility and likelihood of success of the programs (Kobayashi 2004; Budiharta et al. 2016). Study by Soejono and Budiharta (2013) showed that there were some tree species preferred by the local community for rehabilitation of open area around water spring in Pasuruan East Java with the purposes of delivering ecological functions and providing socio-economic benefits. Study of trees preferences conducted by Salam et al. (2000) demonstrated that there are many factors influencing trees preference by farmers in agroforestry system in which the farmers preferred economic benefits rather than ecological concerns.

The selection of tree species for land rehabilitation needs several aspects to consider, including socio-economic aspects, socio-cultural values, environmental services, general performance of tree species and biodiversity aspect whether the species are native or exotic/alien species (Reubens et al. 2011). While there are several studies on ecological aspects of forest and land rehabilitation, there is little information on social aspects particularly regarding community's preference on species selection and land uses management at watershed level. Several previous studies discussed the role of communities in selecting trees for land rehabilitation including trees preferences for water spring rehabilitation (Soejono and Budiharta 2013), rehabilitation of degraded land in Kenya (Glover 2012), selection of tree species in the form of agroforestry for slope stability in North Korea (He et al. 2015), and selection of trees for forest reforestation in the Philippines (Chechina and Hamann 2015). This research aimed to investigate the preference of villagers in selecting tree species for land rehabilitation programs in Sampean watershed, Bondowoso District, East Java, Indonesia and factors that influence those selections in regard to social, economic and ecological objectives of land management. We expect this study can enrich the limited studies on forest and land rehabilitation viewed from social perspective.

MATERIALS AND METHODS

Study areas

This study was conducted in Gubrih sub-watershed, Bondowoso, East Java on April-May 2016. Gubrih sub-watershed is a part of Sampean watershed and encompasses three sub-districts, i.e. Wringin, Tegal Ampel and Pakem. Study location has temperature ranging from 20.4 – 25.9^{0}C with average temperature of 25.7^{0}C. Average rainfall is 6475 mm/year with long rain time is 9 days per month. Minimum rainfall is 1622 mm in June while maximum rainfall is 13102 mm in January. Dry season occurs from June to October while the rainy season occurs from November to May. Soil type that dominates the study location is regosol (Bapeda Jawa Timur, 2013).

Forest cover in Bondowoso is 59.867,95 ha, consisting of watershed protection forest (*hutan lindung*) with an area of 30.863,70 ha that covers 33,99% of Sampean watershed. Other land uses are timber plantation (*kebun pohon*), agroforestry (*kebun campur*), rice field (*sawah*), non-rice crop field (*tegalan*) and settlement area, covering of 7,59%, 19,76%, 27,70%, and 4,62% respectively (Asmaranto et al. 2012). Previous study suggested that the ideal composition of land use in Sampean watershed consists of plantation and agroforestry areas with a portion 28.71% of total extent, rice fields (3.12%), non-rice crop fields (20.27%), and settlement (3.22%) (Asmaranto et al. 2012). The gaps between the ideal and existing conditions especially on tree-based vegetation cover (i.e., plantation/agroforestry) requires study on how to increase such land cover through land rehabilitation.

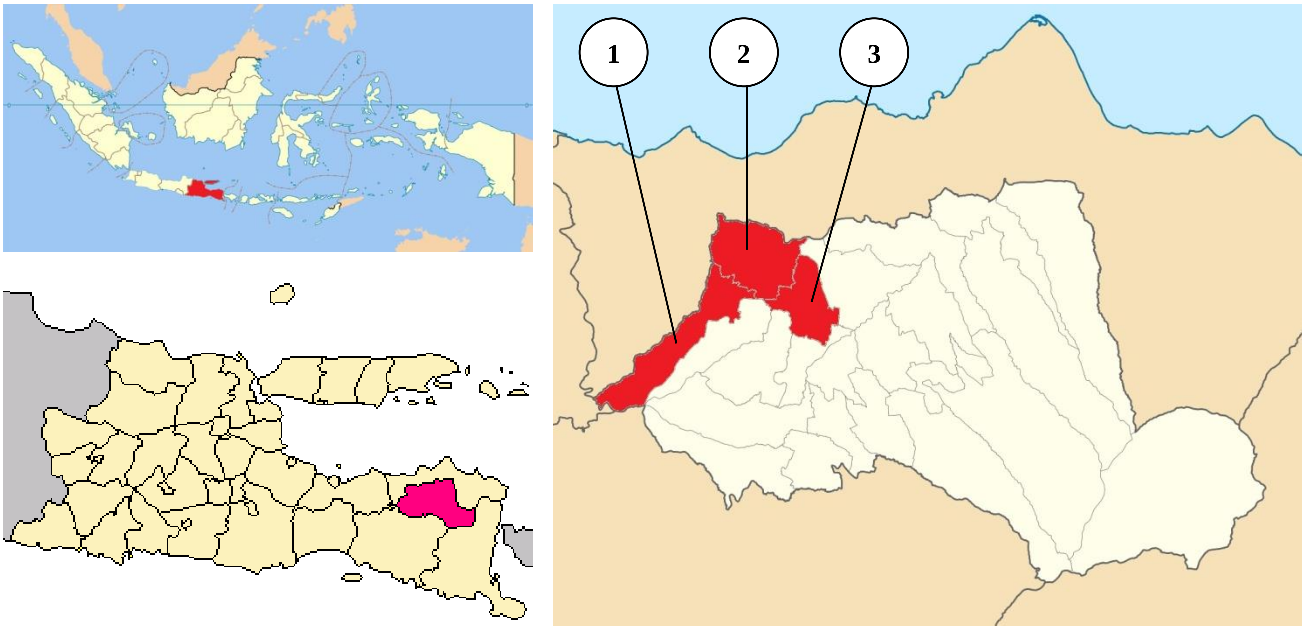

Figure 1. Study location in Gubrih sub-watershed, Sampean watershed, Bondowoso Distric, East Java Province, Indonesia which include Sub-districts of Pakem (1), Wringin (2), and Tegal Ampel (3)

Table 1. Species of trees to select by respondents at the studied areas in Gubrih sub-watershed, Sampean watershed, Bondowoso District, East Java, Indonesia

Species	Family	Local name	Potential uses
Albizia procera (Roxb.) Benth.	Fabaceae	Wangkal	Ecology and economy
Aleurites moluccanus (L.) Willd.	Euphorbiaceae	Kemiri	Ecology and economy
Alstonia scholaris (L.) R. Br.	Apocynaceae	Pule	Ecology
Anthocephalus cadamba (Roxb.) Miq.	Rubiaceae	Jabon	Economy
Antidesma bunius (L.) Spreng.	Euphorbiaceae	Buni	Ecology
Artocarpus altilis (Parkinson ex F.A.Zorn) Fosberg	Moraceae	Sukun	Ecology and economy
Artocarpus heterophyllus Lam.	Moraceae	Nangka	Ecology and economy
Bischofia javanica Blume	Phyllanthaceae	Gintungan	Ecology
Buchanania arborescens (Blume) Blume	Anacardiaceae	Gerok ayam	Ecology
Calophyllum inophyllum L.	Clusiaceae	Nyamplung	Ecology
Cananga odorata (Lam.) Hook.f. & Thomson	Annonaceae	Kenanga	Ecology and economy
Canarium vulgare Leenh.	Burseraceae	Kenari	Ecology
Cassia javanica L.	Fabaceae	Trengguli	Ecology
Ceiba pentandra (L.) Gaertn.	Bombacaceae	Randu	Economy
Coffea arabica L.	Rubiaceae	Kopi	Economy
Diospyros blancoi A.DC.	Ebenaceae	Bisbul	Ecology
Dracontomelon dao (Blanco) Merr. & Rolfe	Anacardiaceae	Rau	Ecology
Durio zibethinus L.	Bombacaceae	Duren	Economy
Dysoxylum gaudichaudianum (A.Juss.) Miq.	Meliaceae	Kedoyo	Ecology
Erythrina orientalis Murray	Fabaceae	Dadap	Ecology
Ficus variegata Blume	Moraceae	Gondang	Ecology
Gmelina arborea Roxb.	Verbenaceae	Gmelina	Economy
Leucaena leucocephala (Lam.) de Wit	Fabaceae	Lamtoro	Economy
Litsea glutinosa (Lour.) C.B.Rob.	Lauraceae	Po ketek	Ecology
Madhuca longifolia (J.Koenig ex L.) J.F.Macbr.	Sapotaceae	Kecik-kecik	Ecology
Michelia alba DC.	Magnoliaceae	Cempaka	Ecology
Pangium edule Reinw.	Achariaceae	Kluwek	Economy
Paraserianthes falcataria (L.) I.C.Nielsen	Fabaceae	Sengon	Economy
Parkia timoriana (DC.) Merr.	Fabaceae	Kedawung	Ecology
Peltophorum pterocarpum (DC.) K.Heyne	Fabaceae	Saga	Ecology
Persea americana Mill.	Lauraceae	Alpukat	Economy
Pipturus sp.	Urticaceae	Senu	Ecology
Pometia pinnata J.R.Forst. & G.Forst.	Sapindaceae	Matoa	Ecology and economy
Syzygium aqueum (Burm.f.) Alston	Myrtaceae	Jambu air	Economy
Pterocarpus indicus Willd.	Fabaceae	Angsana	Ecology and economy
Pterocymbium tinctorium Merr.	Palongan	Sterculiaceae	Ecology
Sapindus rarak DC.	Sapindaceae	Klerek	Ecology
Saraca indica L.	Fabaceae	Asoka	Ecology
Schleichera oleosa (Lour.) Merr.	Sapindaceae	Kesambi	Ecology
Senna siamea (Lam.) H.S.Irwin & Barneby	Fabaceae	Johar	Ecology
Spondias dulcis Parkinson	Anacardiaceae	Kedondong	Economy
Sterculia cordata Blume	Sterculiaceae	Kelumpang	Ecology
Swietenia macrophylla King	Meliaceae	Mahoni	Economy
Syzygium cumini (L.) Skeels	Myrtaceae	Juwet	Ecology
Syzygium polyanthum (Wight) Walp.	Myrtaceae	Salam	Ecology and economy
Tectona grandis L.f.	Lamiaceae	Jati	Economy
Annona muricata L.	Annonaceae	Sirsat	Economy
Bambusa vulgaris Schrad.	Poaceae	Bambu	Ecology and economy
Chrysophyllum cainito L.	Sapotaceae	Buah Susu	Economy
Citrus maxima (Burm.) Merr.	Rutaceae	Jeruk bali	Economy
Cocos nucifera L.	Arecaceae	Kelapa	Economy
Dimocarpus longan Lour.	Sapindaceae	Kelengkeng	Economy
Garcinia mangostana L.	Clusiaceae	Manggis	Economy
Gliricidia sepium (Jacq.) Kunth ex Walp.	Fabaceae	Gamal	Economy
Gnetum gnemon L.	Gnetaceae	Melinjo	Economy
Lansium domesticum Corrêa	Meliaceae	Duku	Economy
Mangifera indica L.	Anacardiaceae	Mangga	Economy
Manilkara kauki (L.) Dubard	Sapotaceae	Sawo	Ecology
Melia azedarach L.	Meliaceae	Mindi	Ecology
Nephelium lappaceum L.	Sapindaceae	Rambutan	Economy
Parkia speciosa Hassk.	Fabaceae	Petai	Economy
Sesbania grandiflora (L.) Pers.	Fabaceae	Turi	Economy

Data collection

This study used questionnaires to collect data which were distributed randomly to respondents. Sampling method used in this survey was simple random sampling. This method allows each member of the population (villager) to have an equal chance of being selected to minimize bias (Groves et al. 2009). Survey was conducted in Gubrih Sub-watershed which encompasses three Sub-districts with total of 15 villages, i.e. Wringin Sub-districts (village: Gubrih, Jambe Wungu, Wringin, Ampelan, Sumber Malang, Jatisari, Banyuwuluh, and Banyuwuluh 2), Tegal Ampel Sub-districts (village: Tanggul Angin, Klabang Agung, Karanganyar, Mandiro, Sekar Putih, Klabang), and Pakem Sub-districts (village: Pakem). Total number of villagers being interviewed was 98 with gender composition of 63 males and 35 females. Each respondent was interviewed according to the list of questions contained in the questionnaire.

The questionnaire contains closed questions about tree species to select by the respondent for rehabilitation in Sampean Sub-watershed. The list of tree species was developed by identifying species with specific criteria in terms of ecological and economic perspectives. The ecological perspectives refer to tree species found at natural ecosystems nearby with similar biotic and abiotic factors, or so-called the reference site (Fiqa and Darmayanti 2017). In addition, tree species with high carbon sequestration were also considered to complement the ecological criteria (Danarto et al. 2013). Carbon sequestration is ability of plants to absorb CO_2 from atmosphere and then store it as biomass (Hairiah et al. 2011). From economic perspective, tree species with economic value were considered. In the end, there were 62 species of trees to be selected by the respondents as shown in Table 1.

In addition to species preference, analysis on factors affecting community preference in selecting particular tree species for land rehabilitation was also conducted. Basic information at respondent level was collected including age, gender, education level, access to transportation to their land (i.e. easy, moderate, difficult), topography of their land (i.e. flat, sloping, and steep), and primary occupation. Respondents were also asked about their perception of the importance and benefit of trees in their life, their preferred land management (i.e. timber plantation/*kebun pohon*, agroforestry/*kebun campur*, rice field/*sawah*, non-rice crop field/*tegalan*), and their acceptance for rehabilitation programs implemented on their lands.

Statistical analysis

Collected data were analyzed using Pearson Chi-square test to examine associations between two variables. In particular, we examined association between the variables of transport access versus preferred land management by the respondent, and between land topography versus preferred land management by the respondent. The equation for the Chi-square analysis is as follows:

$X^2_p = \Sigma \frac{(Fij - Eij)^2}{Eij}$, with df (degree of freedom) = (R-1) (C-1),

Where:
X^2_p = chi-square analysis
F_{ij} = observed value
E_{ij} = expected value
R = number of lines
C = number of columns

The level of confidence to determine significance is 95%, meaning that there is a significant association between variables if p value< 0.05 (Egbue and Long 2012).

RESULTS AND DISCUSSIONS

Respondents' composition

Education level varied among villagers with the highest proportions at the level of elementary school (*Sekolah Dasar*) with percentage of 48.97%, followed by no receiving education with percentage of 12.24% (Figure2). Other educational levels, such as middle level, high level, and college level, had fewer percentage. Variable of age also varied among villagers. Most of respondents in this study had age of more than 40 years, while respondents with age of less than 30 years and between 30-40 years old had equal proportion (Figure 2).

Preferred species of trees for rehabilitation programs by local community

One step in rehabilitation of degraded areas is the selection of species of trees for rehabilitation programs which are preferred by local community to enhance community's acceptance and participation. The results of this study showed that among 62 tree species listed in the questionnaire, there were 45 species chosen by the local community for rehabilitation programs in Gubrih Sub-watershed (Figure 3). Most of the selected tree species have economic potentials, including the potential for wood, fruits, cooking spices and stimulants. Highly preferred tree species are sengon (*Paraserianthes falcataria*), durian (*Durio zibethinus*), gmelina (*Gmelina arborea*), teak (*Tectona grandis*), avocado (*Persea americana*), coffee (*Coffea robusta*), jackfruit (*Artocarpus heterophyllus*), mahogany (*Swietenia macrophylla*), and breadfruit (*Artocarpus altilis*) and mangoes (*Mangifera indica*) in which each of them was selected by more than 20% of the respondents. Tree species such as klengkeng (*Nephelium lappaceum*), jeruk bali (*Citrus maxima*), jabon (*Anthocephalus cadamba*), lamtoro (*Leucaena leucocephala*) and kedondong (*Spondias malayana*) were moderately preferred as it was chosen by 6-20 % of the respondents. As many 21 species were less preferred by community with percentage of respondents ranging from 1-5% including manggis (*Garcinia mangostana*), buni (*Antidesma bunius*), matoa (*Pometia pinnata*), sawo (*Manilkara kauki*), buah susu (*Chrysophyllum cainito*), duku (*Lansium domesticum*), and sirsat (*Annona muricata*) (Figure 3).

Fruit trees are mostly cultivated in homegarden as fruit sources and microclimate controllers (temperature and light intensity controller). In addition, some of species are native trees with potentials of medicine, timber, and food, such as klerek (*Sapindus rarak*), pule (*Alstonia scholaris*), wangkal (*Albizia procera*), turi (*Sesbania grandifolia*), and belinjo (*Gnetum gnemon*). However, these species were chosen by only few respondents because they preferred tree species which has economic benefits for their life including commercial timber trees. For example, sengon (*P. falcataria*) is a timber tree that can be harvested at the age of 5-6 years with wood volume reaching 300 m^3 per hectare with potential income of 240 million rupiahs (Mulyana and Asmarahman 2012). In contrast, although species like klerek (*S. rarak*) has the potentials for batik material, cloth cleaner, soap, biopesticides, acne treatment, shampoo, and shade plant and can be harvested at 5-6 years (Udarno 2012), but this species is rarely cultivated by community since it has limited commercial value.

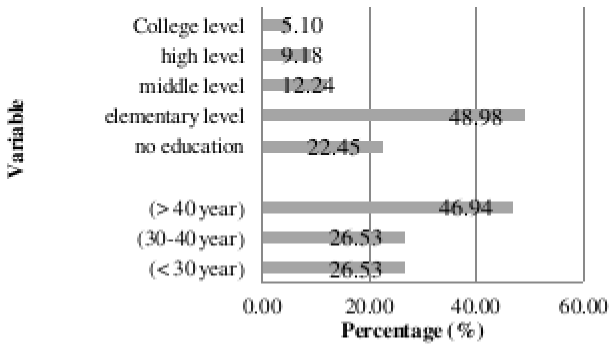

Figure 2. Basic data of respondents (age and education level) at the studied areas in Gubrih sub-watershed, Bondowoso District

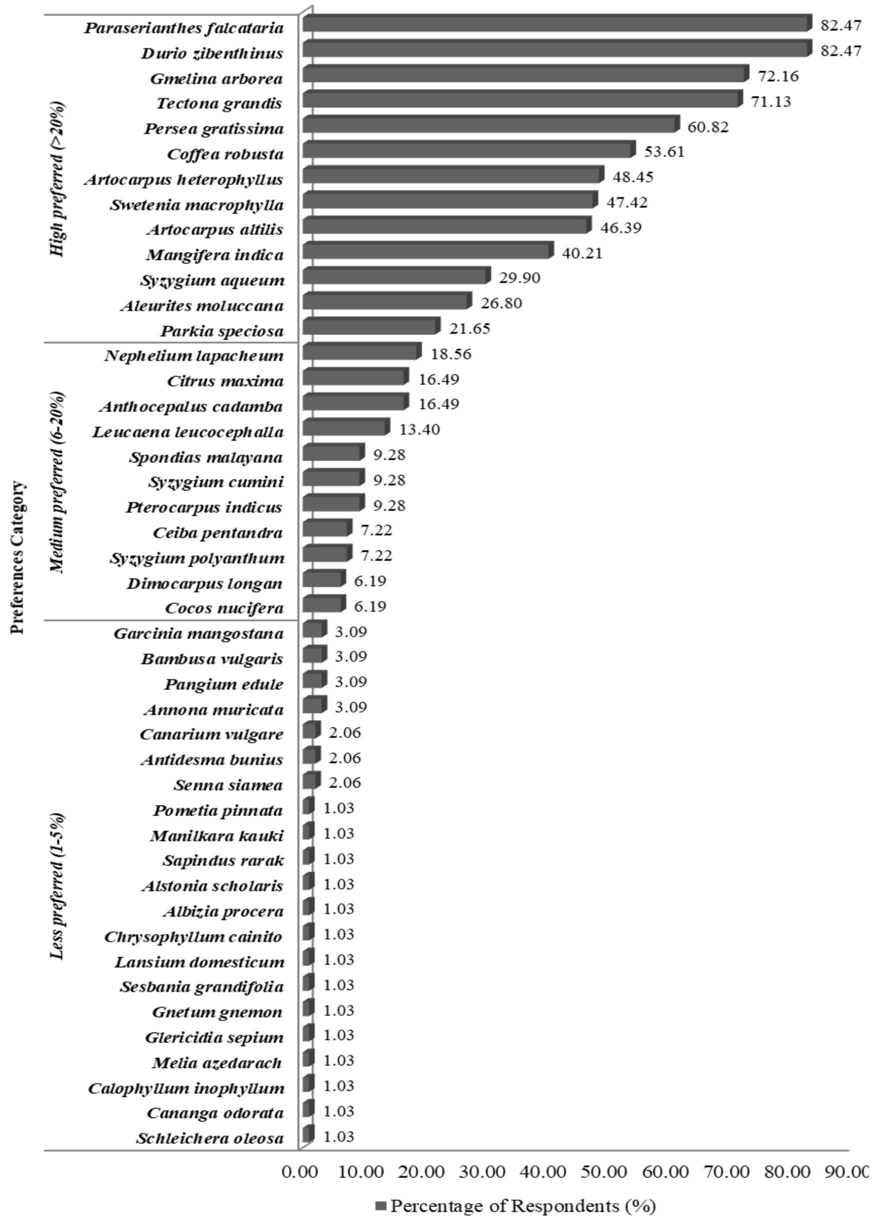

Figure 3. Percentage of respondents and tree species selected (45 species) for rehabilitation programs in Gubrih sub-watershed, Sampean watershed, Bondowoso District, East Java Province, Indonesia

There were 17 species listed in the questionnaire that were not chosen by respondents with most of them are native trees found at the forest of the reference site. Reference site is a site with ecosystem that has similar biotic and abiotic conditions with the land to be restored or rehabilitated. In this study, we referred to trees found at protected forest of RPH Sentul, Probolinggo, East Java that had similar ecosystem conditions with Sampean watershed (Darmayanti and Fiqa 2017). These species included *Bischofia javanica, Buchanania arborescens, Cassia javanica, Diospyros blancoi, Dracontomelon dao, Dysoxylum gaudichaudianum, Erythrina orientalis, Ficus variegata, Litsea glutinosa, Madhuca longifolia, Michelia alba, Parkia timoriana, Peltophorum pterocarpum, Pipturus* sp., *Pterocymbium tinctorium, Saraca indica,* and *Sterculia cordata*. Although these species have biodiversity and ecological values, these species were not chosen by the respondents as they were not familiar with these species. In the other perspective, they assumed that these species lack of economic potentials. Bisbul (*Diospyros blancoi*), cempaka (*Michelia alba*), gerok ayam (*Buchanania arborescens*), gintungan (*Bischofia javanica*), kedawung (*Parkia timoriana*), kedoya *(Dysoxylum gaudichaudianum*), kelumpang (*Sterculia cordata*), walnuts (*Canarium vulgare*), nyamplung (*Calophyllum inophyllum*), krau (*D. dao*), saga (*Peltophorum pterocarpum*) are among 25 tree species that have high potentials in carbon sequestration in dry lowlands ecosystem (Danarto and Yulistyarini 2019). They are also commonly found in water springs of lowland ecosystems, so that the existence of these trees is very important for water conservation (Soejono et al. 2011).

Species of trees with potentials for timber and fruits were chosen by many respondents because these species have economic values. Sengon is one of timber tree categorized as fast-growing species so that it is widely cultivated by local community in Gubrih sub-watershed (Irawanti et al. 2017). Sengon is native to Indonesia, Papua New Guinea, Solomon Island, and Australia. This species can grow in a variety of habitat from dry to moist soil, even in acidic soil with good drainage. In Java, this species can be found on various types of soil with altitudes 0-1200 m above sea level (Soerianegara and Lemmens 1993). Besides sengon, other species which has timber potential in Bondowoso are teak (*T. grandis*), sonokeling (*Dalbergia latifolia*), and gmelina (*G. arborea*). Both jati and sonokeling are species that contribute to high timber production in Bondowoso if compared to other timber trees such as sengon, mahogany, and pine. Data from Bondowoso Statistical Office in 2017 showed that production of timber in 2016 in the form of teak commodities reached 917.9 m^3 with sonokeling wood production reaching 3,049 m^3 (BPS Bondowoso 2017). Teak has been chosen by many people as a long-term investment and has high economic benefits. This tree species is native to India, Indonesia, Laos, Myanmar, Thailand. Teak trees are able to grow in dry to moist habitats with rainfall of 600-4000 mm/year at altitudes of 0-1200 m above sea level with an average annual temperature of 14-36°C. The most suitable soil type is deep, well-drained soil, fertile alluvial-colluvial soil with a pH of 6.5-8 with high levels of calcium and phosphorus (Orwa et al. 2009). Most commercial timber trees planted in Bondowoso are cosmopolitan tree species that have wide adaptation to various climatic conditions and soil types.

Our findings suggest that there is a gap between ecological needs and socio-economic interests in the selection of species for land rehabilitation, especially in watershed landscapes. This is indicated by a mismatch between the list of species with ecological-biodiversity values and species with socio-economic preferences. Previous study in Rejoso watershed, Pasuruan District, East Java, local communities had several criteria in selecting tree species for rehabilitation under PES (Payment for Ecosystem Service) scheme (Leimona et al. 2018). The criteria included the tree species must be suitable with local habitat, it has good prices and accessible market to deliver high revenues, it must-have benefit for domestic consumption and the species possesses environmental and conservation values. Also, local communities preferred trees species that are consistent with their current farming system. Fruit and timber trees were preferred by smallholders downstream while agroforestry was mostly cultivated upstream (Leimona et al. 2018).

In various rehabilitation programs of degraded areas in Indonesia, tree species such as sengon, teak, gmelina, and jabon are widely planted by communities because these species have economic values. However, the lifetime of these species is not long because they would be harvested for their timber yield so that the rehabilitation goals for environmental improvement are not achieved (Soejono and Budiharta 2013). One of alternative for rehabilitation of degraded areas is using non-timber producing species which has long-term economic and environmental improvement potentials. From the selection of the villager population at the study sites, we propose several species of non-timber produced species that can be used for land rehabilitation in the studied area, including durian (*D. zibethinus*), avocado (*P. americana*), coffee (*C. robusta*), jackfruit (*A. heterophyllus*), mango (*Mangifera indica*), water guava (*Syzygium aqueum*), candlenut (*Aleurites moluccana*), petai (*Parkia speciosa*), rambutan (*N. lappaceum*), jeruk bali (*C. maxima*), and lamtoro (*L. leucocephala*). When cultivated, these species can be combined to form multi-strata agroforestry which not only can deliver non-timber products but also contributes to conserve water and soil (Budiharta et al. 2016).

Planting tree species for rehabilitation needs to consider habitat suitability, soil type, texture, soil structure and depth, climate, and water use efficiency (Soejono et al. 2011). Based on interviews with local community at the research location supported by literature studies from Orwa et al. (2009), Krisnawati et al. (2011), Harja et al. (2009), Soerianegara and Lemmens (1993), suitable habitat of trees species selected by the local community can be divided into three ranges of altitudes, namely low (0-400 m asl), medium (500-900 m asl) and high altitudes (mountainous with altitude > 900 m asl). Most of the tree species chosen by the local community at the studied areas can be planted from lowland to highland areas, including sengon (*P.*

falcataria), gmelina (*G. arborea*), teak (*T. grandis*), avocado (*P. americana*), jack fruit (*A. heterophyllus*), mahogany (*S. macrophylla*), bread fruit (*A. altilis*), mangoes (*Mangifera indica*), guava (*S. aqueum*), candle nut (*Aleurites moluccana*), and lamtoro (*L. leucocephala*). On the other hand, the preferred species that can be cultivated from lowland up to medium altitudes are durian (*D. zibethinus*), guava (*S. aqueum*) and rambutan (*N. lappaceum*). While jeruk bali (*C. maxima*) can only be cultivated in lowland ecosystems. Suitable habitat for the preferred trees by the local community in the studied area is shown in Table 2.

The research location has an average rainfall of 1000-2500 mm/year with soil is categorized as clay and loam soil. Durian (*D. zibethinus*) is cultivated by villager from middle to highland combined with other fruit trees such as avocado (*P. americana*), coffee (*C. robusta*), banana (*Mussa accuminata*), rambutan (*N. lappaceum*), and jeruk bali (*C. maxima*). Bondowoso is one of district that supplies durian in Indonesia with total production of 11.196 tons (Fitri and Islahudin 2018). Other species such as coffee (*C. robusta*) are cultivated from middle to highland and can be combined with other fruit trees within agroforestry system. Coffee is suitable to be cultivated within the range of altitude from 1300 to 3000 m asl with temperature of 15-25^{0}C and average rainfall 500-2000 mm/year. Soil classes suitable for coffee cultivation are loamy soil with deep solum, slightly acid, and well drainage. The soils should be rich in nutrients especially potassium with generous supply of organic matter (Orwa et al. 2009). Agroecologically, both plants are suitably cultivated in Bondowoso. A previous study showed that avocado, durian, clove and perennial crops that were combined in agroforestry systems in Bondowoso were profitable with NPV (Net Present Value) of Rp. 21.483.580 per hectare (Hariyati 2013).

Local community perception toward land rehabilitation

The results of the survey indicated that local community in Gubrih sub-watershed, Sampean watershed has a different perception regarding land rehabilitation in their area (Figure 4). The figure shows that the respondents in the area understood the importance of trees in their lives and trees deliver benefits to them. However, there were some respondents saying that trees are not important for their lives and they also have poor knowledge about the benefits of trees.

The perception of local people about the importance of trees in their lives indicates that local people use trees for various needs, including as income sources, conserving spring water, and disaster mitigation with most of them stating that trees are important for the purpose to increase income. Bondowoso is one of the poor regions (*daerah tertinggal*) in Indonesia with problems including low human development index, poverty, and lack of basic facilities, such as health, education and road infrastructure (Bondowoso Spatial Plan Agency 2011; Puspasari and Koswara 2016). Community welfare in Bondowoso needs to be increased to reduce the poverty level. There is 90.08% of total land area in Bondowoso used for agricultural land, including rice fields, non-rice crop fields (*tegalan*), plantations, forestry, swamps, and ponds. Most villagers in Bondowoso work in the sector of agriculture, forestry, and fisheries. Commodities cultivated in plantations in Bondowoso include coconut, areca nut, kapok, cashew nut, arabica coffee, robusta coffee, cloves, kasturi tobacco, sugar cane, and tobacco, whereas fruit species include mango, banana and durian (BPS Bondowoso 2018). Since most of the communities in the survey locations utilized trees and plants as a source of income, this can be combined with efforts to rehabilitate land by focusing on species with multiple benefits, not only to improve environment quality (i.e. ecological objective) but also to enhance community's welfare (socio-economic objective). The potential land management system to support rehabilitation efforts in the study region includes plantation of timber species and agroforestry system which can be implemented in land management currently under non-rice crop field (*tegalan*).

Influencing variables of community's preference

Land topography and access influenced the preference of land use systems by local community in Gubrih sub-watershed. Based on the results of Chi-square Pearson statistical analysis, there was a correlation between topography and the selection of land management systems by local community (p-value<0.05). Dryland agricultural systems, either in the form of *padi gogo* rice field or other crops field (*tegalan*) were mostly preferred by villagers from low to medium altitudes and on flat locations, but this was not the case in the area with steep topography in which most respondents preferred agroforestry (Figure 5).

There was also a correlation between variable of access and the selection of land management systems by community with Chi-square Pearson value of 10.33 (p-value<0.05). For all categories of access (i.e., easy, moderate and difficult), many villagers preferred plantation of timber species and agroforestry system because they assumed that both systems of land use were profitable (Figure 6). Yet, for all categories of access, land use system of dry land rice cultivation (*padi gogo*) was still chosen by the villagers although the percentage was smaller than plantation of timber species and agroforestry.

The finding of the relationship between land management and accessibility is in accordance with other studies. The more difficult is the access of a land management system, the higher is the likelihood a land being managed for tree-based land-use systems such as forest and agroforestry. Vice versa, the easier is the access to transportation, the more likely a land is managed under intensive agriculture, such as rice field and non-rice crop fields (*tegalan*). Several factors that influence land use functions in watersheds include the presence of infrastructure, agricultural expansion, timber extraction. Access to transportation triggers migration and forest clearing for plantations (Geist and Lambin 2002; Verbist et al. 2005; Busch and Gallon 2017).

Table 2. Environmental suitability for 14 species preferred by local community in Gubrih sub-watershed, Sampean watershed, Bondowoso District, East Java Province, Indonesia

Species	**Altitude (m asl)**	**Soil type**	**Potentials**	**References**
Paraserianthes falcataria	0-1200	Deep, well-drained fertile soils, such as friable clay loam. Prefers alkaline to acid soils.	Timber	Orwa et al. (2009)
Gmelina arborea	0-1200	Preference for moist, fertile, freely drained soils; acid soils, calcareous soils and laterite soils.	Timber	Orwa et al. (2009)
Tectona grandis	0-1200	Their most suitable soil is deep, well-drained, fertile alluvial-colluvial soil with a pH of 6.5-8 and a relatively high calcium and phosphorous content. The quality of growth, however, depends on the depth, drainage, moisture status and fertility of the soil. Teak does not tolerate waterlogging or infertile lateritic soils.	Timber	Orwa et al. (2009)
Persea americana	0-2500	Requires well-drained aerated soil. A pH of 5-5.8 is optimal for growth and fruit yield.	Fruit	Orwa et al. (2009)
Artocarpus heterophyllus	0-1600	Deep, alluvial, sandy-loam or clay loam soils of medium fertility, good drainage and a pH of 5-7.5. This species tolerance to saline soils	Timber, fruit and vegetable	Orwa et al. (2009)
Swietenia macrophylla	0-1500	Well-drained soils.	Timber	Orwa et al. (2009)
Artocarpus altilis	0-1550 (optimum growth at 600-650)	Alluvial and coastal soils, deep, fertile, well-drained sandy loam or clay loam soils.	Timber, fruit and vegetable	Orwa et al. (2009)
Mangifera indica	0-1200	Mango trees thrive in well-drained soils with pH ranging from 5.5 to 7.5 and are fairly tolerant of alkalinity. For good growth, they need deep soil to accommodate the extensive root system.	Fruit	Orwa et al. (2009)
Syzygium aqueum	0-1200	The trees prefer heavy soils and easy access to water instead of having to search for water in light deep soils.	Fruit	Panggabean (2016)
Aleurites moluccana	0-1200	Sandy, clay, loam soil with pH 5-8.	Spices	Krisnawati et al. (2011)
Leucaena leucocephala	0-1500	Optimal growth on calcareous soils but can be found on saline soils and on alkaline soils up to pH 8; it is not tolerant of acid soils or waterlogged conditions. *L. leucocephala* is known to be intolerant of soils with low pH, low phosphorus, low calcium, high salinity, high aluminum saturation and water-logging and has often failed under such conditions.	Fruit, firewood	Orwa et al. (2009)
Durio zibethinus	300-800	Deep soil, well-drained, light sandy or loamy soil.	Fruit, timber	Orwa et al. (2009)
Nephelium lappaceum	0-600	Clay loam soil, pH 5-6.5.	Fruit	Orwa et al. (2009)
Citrus maxima	0-400	Tolerate from coarse sand to heavy clay	Fruit	Orwa et al. (2009)

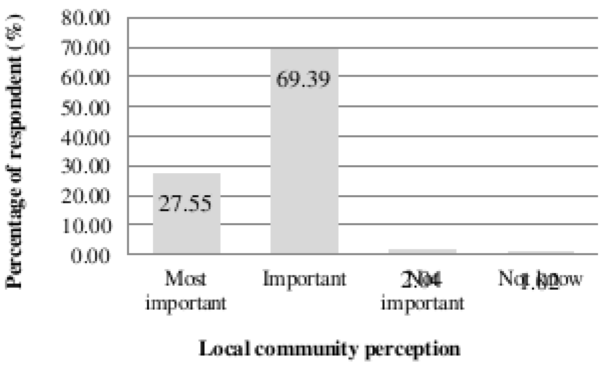

Figure 4. Perception of local community on the benefit of trees in their life

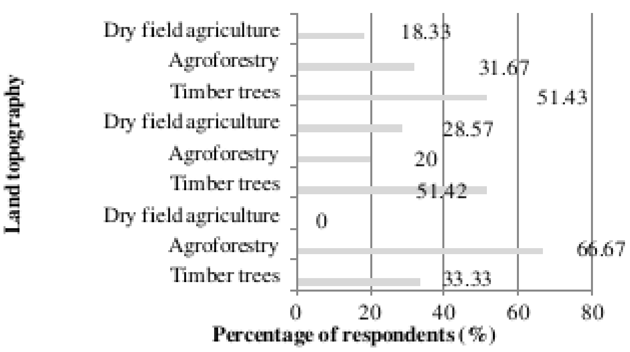

Figure 5. Land use system preferred by local community based on categories of land topography

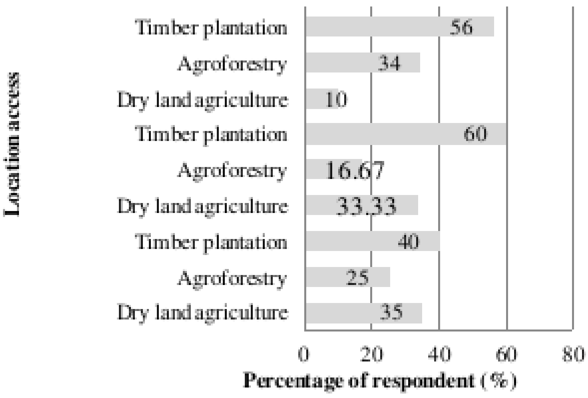

Figure 6. Land use system preferred by local community based on categories of location access

Based on interviews with respondents, timber plantation and agroforestry were considered to have economic advantages compared to other land uses. Agroforestry system is ecologically and economically beneficial. Agroforestry system at the studied area was a mixed system of combination of several species of fruit trees and seasonal crops. The villagers at the survey location stated that the agroforestry system increased income of their life. Difficult access to transportation to traditional markets causes local communities preferred for agroforestry and timber plantation for economic investment purposes.

Agroforestry increases community income and environmental services compared to conventional farming systems (Mercer et al. 2014). A previous study showed that coffee farming in Bondowoso is beneficial with R/C is 1.85. Another study showed that commercial agroforestry in India is profitable with Benefit to Cost (B/C) ratio is 6.59 for annual crop-based tree agroforestry (Sangeetha et al. 2015). A case study in East Kalimantan, vanilla and agarwood agroforestry are also profitable with profit rate of 15% and IRR of 21.5% (Kunio and Lahjie 2015) while agroforestry in Sukoharjo Pringsewu Village contributes to the income of farmers with benefit percentage of 88.31% (Olivi et al. 2015).

In conclusion, of the 62 tree species listed in the questionnaire, there were 45 species of trees selected by respondents in Gubrih sub-watershed with 13 species were highly preferred. The respondents understood the importance of trees as a source of income as well as a measure to conserve spring water and mitigate disasters, such as landslides and floods. This selection of species was strengthened with land-use systems they preferred, which were tree-based land-use systems such as plantation of timber species and agroforestry. This preference is influenced by access to transportation and land topography. The findings of this study suggest that there is opportunity in rehabilitating degraded lands in Sampean watershed using tree species preferred by local communities under the land use system of timber plantation or agroforestry. A list of species resulting from this study can provide insights when establishing nurseries and producing seedlings for rehabilitation programs.

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