Research article

Agroforestry to Support Trees and Protect Against Air Pollution: A Review

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Abstract.
The high rate of land conversion may jeopardize natural resources vital to Balinese culture, as well as the forest's ability to maintain a healthy environment. Agroforestry is thought to have a significant environmental benefit in terms of reducing air pollution and respiratory diseases. This research aimed to find a solution to reduce air pollution that is harmful to people's health. Relevant articles were found by searching through databases such as Google Scholar, Research Gate, Wiley Online Library, and others. According to the findings, respiratory diseases have been increasing and these have been linked to rising air pollution, implying that air pollution facilitates viral infections. Forest cover should be increased to help reduce air pollution caused by fossil fuel combustion from road traffic. It is proposed that increasing the production of tolerant crops in mixed culture with trees can help to maintain tree cover. Agroforestry is becoming an important complement to the native forest in terms of protecting people from air pollution and respiratory disease.

Keywords: agroforestry, tree protection against air pollution, land conversion, deforestation

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1. Introduction

The culture and nature of Bali have made the island a main tourist destination of the world since the very early 20^{th} century. Tourism then becomes an important industry and many people rely on this industry for their income. Hotel, restaurant, transport and other infrastructure developed which benefitted not only Balinese people but also nationally. Balinese culture is conserved by the introduction of "Culture tourism" and also its nature by the strict implementation of "Trihitakarana". Similar to what occurred after the industrial revolution during the mid of 18^{th} century, the tourism industry also resulted in better welfare, urbanization and the explosion of population. This development required more accommodation and other infrastructures which inevitably caused more area of plant's cover converted and road traffic is more crowded. When the covid-19 pandemic then breakout in 2020, the world curiously finds out the cause and solution to minimize

casualty. With the involvement of researchers worldwide, the cause of the pandemic identified as Sarcov-2 which make a severe disease in human respiratory organs. It is speculated that this disease is closely related to air pollution and forest cover is proposed to be very important to protect people from the diseases. Accordingly, to resume the loss of plants coverages after it had been previously converted for the development of infrastructures, agroforestry may then be a potential alternative to maintain trees protection against air pollution and sustain natural resources to support Balinese culture.

2. Methodology

This review was written after reading and understanding literature collected using search engines, such as Wiley Online Library, Google Scholar, ResearchGate, etc. Free access relevance articles from a journal were then opened and downloaded. There were more than 100 articles found related to agroforestry, trees protection against air pollution, land conversion, deforestation, offering plants, etc. About 26 papers were selected for this review based on the publishing date and its relevance to the topic written.

3. Result and Discussion

3.1. Air pollution and the respiratory infectious diseases

Fossil fuel has been used to generate energy since the industrial revolution in the early 19^{th} century and the cloud of smoke from coal combustion has resulted in various damages. However, air pollution did not become a subject of examination during the period [1]. The most significant problem occurred in 1952 when smoke concentration was more than 50 times above the limit and mortality was 3 fold [2]. In 1970, the word “environment” was frequently used in Japan because pollutants such as Mercury, CO and NO_2, resulted in societal problems [3] and the Clean Air Act in 1970 in the USA reduced air pollution from industry [2]. The effect of air pollution on global warming was then widely discussed since 1980 and the Kyoto protocol, which was an attempt to reduce gas emission, commenced to act in 2005 [4]. After 5 years of implementation of the Kyoto protocol, the world is surprised by the quick spread of serious respiratory infection diseases which then prompted WHO to announce a pandemic [5]. Since various convincing studies, which relate respiratory infection disease to air pollution,

have been previously reported, the pandemic that occurs after the reduction of gas emission raises the question of whether air pollution facilitates the outbreak of the diseases.

Depending on the type of pollutants, air pollution may cause infection in the upper or lower respiratory system or hardened asthmatic and cardiovascular diseases. Studies that were conducted in 1991-1992 found that during the episode of fine particulate air pollution, dyspnoea was increased in children with asthma [6]. In another study, [7] published a report on the association of air pollutants on hospital visits. The authors measured air pollutants from 1993 to 2000 and collected hospital visit records from 37 hospitals. This study found that a 2 μg/m^3 increase of $PM_{2.5}$ organic carbon was associated with a 3% increase in pneumonia visits and standard deviation increases of NO_2 and CO was associated with specific respiratory conditions. A more detailed review on the association of air pollution, particularly NO_2, with respiratory illness was reported by [2]. According to these authors, air pollution (NO_2) could impair alveolar immunity, bronchial macrophage function and pathological abnormality of the upper and lower respiratory tract. Thus $NO_{2,}$ which is generated during the combustion of fossil fuel in motor traffic [8], facilitates the virus to infect respiratory cells. The various study that was then conducted after the outbreak of covid-19 is in agreement with the review by [2]

A respiratory infection can be reduced or eliminated by interruption of bioaerosol transmission in 3 steps, reducing the release of the pathogen at the source, impeding transportation by air and protecting susceptible persons [9]. During this current pandemic, wearing a face mask has been found effective to reduce transmission [10]. For example, Covid -19 incidence was decreased in a country with a mask mandate but continuously increased in the country without a mask mandate. As evidenced by other studies, the decrease of covid-19 incidents most likely attributed to the filtering mechanism of the mask against both virus and pollutant. [11] reported a study, which using hospitalized rate as a dependent variable and $PM_{2,5}$as the independent variable, found an increased in hospitalized rate and $PM_{2.5}$. Suggesting that covid-19 incidence is attributed to both virus infection and air pollution where according to [12] air pollution facilitates the infection by lowering the response of the immune system.

3.2. Air pollution and tourism

Whilst the tourism industry has expanded rapidly since 1950 [13], tourism in Bali has taken off since 1924 [14]. According to this author, the commencement of tourism in

Bali was initiated by launching a weekly steamship service connecting Bali-Surabaya-Makassar-Batavia. When the Bali hotel was opened in 1928, the number of visitors was growing from hundred to thousand. In 1970, mass tourism was launched by the Indonesian government. In 2000, the total number of foreign tourists arriving in Bali was 1,412,839, in 2005 was 1,386,449 and in 2006, the population of Bali was 3247772 (Balitourismboard.org). This makes the ratio of tourists and the local population is about 1:2.3. Based on this ratio, it can be speculated that tourism affects air pollution in Bali. However, the effect may be markedly different between the period before and after the industrial period and depending upon parameters include; the number of tourists to visit, accommodation and transport systems.

By using a Generalized Additive Model in its semi-parametric form on the daily concentration of PM_{10} and the number of tourists in Mallorca (Spain), [15] found that an increase in 1% tourist number, PM10, was increased by 0.45%. Inferring that before the tourism industry was expanded in Bali, the air pollution is lower than that after the expansion of the tourism industry. However, since Bali depends on the tourism industry for domestic income, it is expected that tourist arrival remains at the same rate but air pollution can be reduced to a healthy standard. An alternative that can be implemented to reduce pollution is by increasing the tree population.

3.3. Trees protection against air pollutions

The tree is an autotrophic organism which converts inorganic compound into the organic compound, predominantly in leaves, for growth and reproduction [16]. Energy for the process is harvested by the trees from the sun and inorganic compounds such as CO_2 is taken up from the atmosphere. The process which is well known as photosynthesis releases O_2 into the atmosphere via a pore in the leaf known as stomata. This natural activity is characteristic of photosynthetic plants, e. g. trees. Therefore, the plants could eliminate CO_2 air pollution naturally and adapt to the atmospheric CO_2 concentration [17]. However, the air pollutants which result whether by human activity such as the combustion of fossil fuel in the road traffic [18] or naturally such as volcano eruption, contain not only CO_2. The other air pollutant that could threaten public health when its concentration is above the threshold limit includes fine particles with a diameter less than 2,5 µm ($PM_{2.5}$), less than 10µm (PM_{10}), NO_2, CO, SO_2, etc.[19].

After the outbreak of the existing Covid 19 pandemic, serious attention should be taken to the impact of air pollution since Covid-19 is a respiratory infected disease [12] that is closely related to air pollution. Various studies have been reported on the

capacity of trees to reduce air pollution. For example, [20] reported a study on the removal of air pollutants, NO, CO, PM_{10} by dry deposition on trees. According to these authors, a coniferous forest that covers 25% of the study area absorbs 21% of the air pollution attributed to high forest cover density and duration of leaf life-span. Suggesting that by increasing the forest cover, the healthier air inhaled by the people in the area. Removal of PM_{10} in Strasbourg city of Franc was reported by [21]. These authors use the I tree model, which requires tree structure information and air pollution data, to measure the removal of PM_{10} from the atmosphere. It was found that the overall public green area was about 27.80% of the city area and consisted of various species such as *Fagus syl-vatica*, *Corylus avellena*, *Fraxinus excelsior*, etc. The green area trees in public green spaces in Strasbourg removed about 88.23 tons per year of pollutants. The mechanism by which the pollutant removed from the air involving (1) wet deposition, transfer of pollutant to cloud droplet before falling with the rain, (2) gas-phase reaction which make aerosol before deposition via a wet or dry mechanism, (3) dry deposition, gaseous or particulate pollutants dry deposited on a various surface such as the leaf of trees [22].

The effectiveness of trees to remove pollutants from the air because trees have a large amount of leaf area and their structure could result in air turbulence movement [23]. Therefore, the taller the trees the capacity to remove pollutants is becoming higher. Depending on the type of air pollutants, the trees remove the pollutants via a different mechanism. Gaseous pollutants such as SO_2 and NO_2 are taken up by the plants via stomata and particulate matter are taken up by deposition on the leaf. The gaseous pollutant however is toxic to the plants when its concentration is above the threshold limit because the pollutant could lower cytoplasmic pH. Suggesting that more trees are required to reduce the concentration of air pollutants.

3.4. Agroforestry for sustaining trees and natural resources to support Balinese culture

The important activity for the Balinese people in carrying out Hindu religious ceremonies is making an offering known as Banten. One of the biggest ceremonies in Bali is Galungan and Kuningan Day which is believed to be the days when the Balinese's ancestors descend from heaven during Galungan and back to heaven during Kuningan Days. Various offerings are made by Balinese people involving the use of various plant parts such as leaf, flower, fruit and stem from various plant species. Suggesting that Balinese people need to plant various species whether in their back yard such as

ornamental plants or on their plantation, such as bamboo, trees, coconut, banana, etc. So, traditionally, Balinese people have developed agroforestry which is the term for land-use systems and technologies in which woody perennials (such as trees, shrubs, palms or bamboos) and crops or animals are deliberately grown on the same parcel of land [24]. However, because of economic developments or other factors, the agroforestry system may have been developed into an intensive system or converted into other uses which then make fewer trees cover on the island of Bali. According to [25], global forest cover is 30.8% of the global area and approximately 0.5 ha per person. But this forest cover is not distributed equally, e. g. forest area in Bali in 2018 was 22.9% and approximately 0.047 ha/person (BPS Bali). Assuming that global forest cover (30.8%) is sufficient to reduce air pollution, there is still much effort to be performed to make a healthy environment in Bali, particularly because the ratio of forest cover per person is about 10 fold lower than that of global forest cover.

During the current existing problem worldwide, i. e. the breakout of the covid-19 pandemic, the various methods may be employed to increase the area of forest cover per person. For example, improving urban forests and increasing trees cover in the agroforestry system. However, since the efficiency of plant production in agroforestry is regarded as lower than the intensive system [26], new techniques should be implemented, such as a sustainable farming system.

4. Conclusion

Various literature supports the link between air pollution and respiratory infection diseases and covid-19. Various literature also shows that the tourism industry contributed to the increase in air pollution. Thus, since forest cover could decrease the air pollution, reducing air pollution while maintaining tourist arrival rate can be achieved by increasing the area of land cover with trees or forest. For example, improving the efficiency of crop production in mixed cultures with trees or forests. Under the condition of the existing pandemic, improvement of tree covers is regarded as crucial to reducing air pollution which threatens public health.

References

[1] Akatsu M. The problem of air pollution during the industrial revolution. Monograph Series of the Socio-Economic History Society, Japan. Sugiyama S, editor. Tokyo: Springer; 2015.

[2] Chauhan A, Johnston S. Air pollution and infection in respiratory illness. British Medical Bulletin. 2003;68:95–112. https://doi.org/10.1093/bmb/ldg022

[3] Ueda M. The history of ecological environment: Ideas derived from Chinese research. Monograph Series of the Socio-Economic History Society, Japan. Sugiyama S, editor. Tokyo: Springer; 2015.

[4] Cirman A, Domadenik P, Intriago R. The Kyoto protocol in a global perspective. Economic and Business Review. 2009;11(1):29–54.

[5] Zanke A, Thenge R, Adhao S. COVID-19: A pandemic declare by World Health Organization. IP International Journal of Comprehensive and Advanced Pharmacology 2020;5(2):49–57. https://doi.org/10.18231/j.ijcaap.2020.012

[6] Peters A, Dockery D, Heinrich J, Wichmann H. Short-term effects of particulate air pollution on respiratory morbidity in asthmatic children. European Respiratory Journal 1997;10(4):872–879. https://doi.org/10.1183/09031936.97.10040872

[7] Peel J, Tolbert PE, Klein M. et al. Ambient air pollution and respiratory emergency department visits. Epidemiology. 2005;16(2):164–174. https://doi.org/10.1097/01.ede.0000152905.42113.db

[8] Gehring U, Cyrys J, Sedlmein G. et al. Traffic-related air pollution and respiratory health during the first 2 yrs of life. European Respiratory Journal 2002;19(4):690–698. https://doi.org/10.1183/09031936.02.01182001

[9] Dhand R, Li J. Coughs and sneezes: Their role in transmission of respiratory viral infections, including SARS-CoV-2. American Journal of Respiratory and Critical Care Medicine. 2020;202(5):651–659. https://doi.org/10.1164/rccm.202004-1263PP

[10] Gandhi M, Marr L. Commentary uniting infectious disease and physical science principles on the importance of face masks for. Med (N Y). 2021;2(1):29–32. https://doi.org/10.1016/j.medj.2020.12.008

[11] Cascetta E, Henke I, Francesco L. The effects of air pollution, sea exposure and altitude on Covid-19 hospitalization rates in Italy. International Journal of Environmental Research and Public Health 2021;18(452):1–11.

[12] Bourdrel T, Annesi-Maesano I, Alahmad B, Maesano C, Bind M. The impact of outdoor air pollution on Covid-19: A review of evidence from in vitro, animal, and human studies. European Respiratory Review 2021;30:1–18. https://doi.org/10.1183/16000617.0242-2020

[13] Holden A. Environment and tourism. London: Routledge; 2000.

[14] Picard M. Cultural heritage and tourist capital: Cultural tourism in Bali. International Tourism: Identity and Change. JA, Lanfant MF, editors. London: Sage; 1995.

[15] Saenz-de-Miera O, Rosselló J. Modeling tourism impacts on air pollution: The case study of PM10 in Mallorca. Tourism Management 2014;40:273–281. https://doi.org/10.1016/j.tourman.2013.06.012

[16] Kreuzwieser J, Gessler A. Global climate change and tree nutrition: Influence of water availability. Tree Physiology 2010;30(9):1221–1234. https://doi.org/10.1093/treephys/tpq055

[17] Franks P, Leitch I, Ruszala E, Hetherington A, Beerling D. Physiological framework for adaptation of stomata to CO2 from glacial to future concentrations. Philosophical Transactions of The Royal Society B Biological Sciences 2012;367(1588):537–546. https://doi.org/10.1098/rstb.2011.0270

[18] Rindy J, Ponette-González A, Barrett T, Sheesley R, Weathers K. Urban trees are sinks for soot: Elemental carbon accumulation by two widespread oak species. Environmental Science & Technology 2019;53(17):10092–10101. https://doi.org/10.1021/acs.est.9b02844

[19] Perera F. Pollution from fossil-fuel combustion is the leading environmental threat to global pediatric health and equity: Solutions exist. International Journal of Environmental Research and Public Health 2018;15(16): 1-17. https://doi.org/10.3390/ijerph15010016

[20] García de Jalón S, Burgess PJ, Curiel Yuste J. et al. Dry deposition of air pollutants on trees at regional scale: A case study in the Basque Country. Agricultural and Forest Meteorology 2019;278(107648):1–17. https://doi.org/10.1016/j.agrformet.2019.107648

[21] Selmi W, Weber C, Rivière E, Blond N, Mehdi L, Nowak D. Air pollution removal by trees in public green spaces in Strasbourg city, France. Urban For. Urban Green. 2016;17(2):192–201. https://doi.org/10.1016/j.ufug.2016.04.010

[22] Nowak DJ. Chicago's urban forest ecosystem: Urban forest climate project. McPherson RA, Gregory E, Nowak DJ, editors. Pennsylvania: Northeastern Forest Experiment Station; 1994.

[23] Sing S, Verma A. Environmental bioremediation technology. Singh S, Tripathi R, editors. Berlin: Springer-Verlag Berlin Heidelberg; 2007.

[24] Borelli S, Simelton E, Aggarwal S, et al. Agroforestry and tenure. Food and Agriculture Organization of The United Nations, International Centre for Research in Agroforestry. Vol. 8. 2019. Rome.

[25] Food and Agriculture Organization of the United Nations, UN Environment Programme. The state of the world's forests. Rome: UNEP; 2020.

[26] Watteyn C, Fremout T, Karremans AP. et al. Vanilla distribution modeling for conservation and sustainable cultivation in a joint land sparing/sharing concept. Ecosphere. 2020;11(3). 1-18. https://doi.org/10.1002/ecs2.3056