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SUSTAINABLE PRODUCTIVITY OF VIETNAMESE COFFEE FARMS BY INTER-PLANTING WITH *MACHILUS ODORATISSIMA* NEES: A CASE STUDY IN QUANG TRI PROVINCE, VIETNAM

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Abstract. This study assesses the positive effects of inter-planting *Coffea arabica* and *Machilus odoratissima* Nees over seven years in small-scale farms in Huong Hoa district, Quang Tri province, Vietnam. The results show that the environmental conditions for growing and developing the coffee trees improve in the area of mix-planting *Coffea* and *Machilus*. Compared with monoculture farms, the inter-planting farms experience the wind speed decreased to 1.67 $m \cdot s^{-1}$, the soil moisture increased by 5.1%, and the soil temperature decreased by 3.6 °C. The coffee yield increases by approximately 7.5%. In addition, *Machilus* products also contribute to economic efficiency and the sustainability of coffee farms (716.52 USD/ha). This could be considered financial support to the farmers to maintain the coffee plantations in harsh weather conditions or in uncertain prices of productions.

Keywords: Coffea arabica, inter-planting, Machilus odoratissima Nees, sustainable productivity, Quang Tri, Vietnam

1 Introduction

Vietnam is one of the countries with the highest coffee production globally [17, 35, 36]. However, recent studies have shown that the coffee productivity and quality of Vietnam have decreased, and the area of coffee farms fluctuates significantly [9, 12, 25, 28, 31]. The fluctuation of seed quality and price [42, 45] and the impact of climate change are the most crucial factors affecting coffee farms locally and globally [5, 13, 14, 21]. Inter-planting *Coffea* with other species has been considered a sustainable solution for coffee farms and plantations [7, 8, 15, 26, 41]. Quang Tri is a province in the central region of Vietnam and has about 5,100 ha of coffee farms with a high annual raw production of 100,000 tons. The coffee farms significantly provide income to more than 8,620 households [37]. The coffee variety in Quang Tri is primarily *Coffea arabica*. The farmers cultivate only *Coffea* with a large amount of fertilizer. The plants are weeded but not watered. Therefore, the coffee trees grow poorly, resulting in a low annual yield of about 11–12 tons of raw coffee/ha [37]. In the context of clime change, the drought lasts longer, and the wind becomes stronger and drier. Such climate factors significantly affect the growth and production of the

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coffee trees planted in Huong Hoa district, Quang Tri province. According to a previous survey, approximately 2% of the total households inter-plant *Coffea* with *Machilus odoratissima* or other species to increase the shade and protect the coffee trees from wind in the dry season. This cultivation technique has been successfully adopted in many countries [4, 22, 29], but it is relatively new in Vietnam. Shading and protecting the coffee trees [10], *Machilus odoratissima* is an appropriate inter-cropping species for a sustainable coffee plantation. However, specific effects of this model have not been reported. Therefore, this study evaluates the effectiveness of inter-planting plantations of *Coffea arabica* and *Machilus odoratissima* with a hope to enhance coffee production locally and nationally.

2 Materials and methods

2.1 Description of study area

This study was conducted at Chenh Venh village, Huong Phung commune, Huong Hoa district, Quang Tri province, Vietnam. The site is located between latitude 16°46′ North and longitude 106°33′ East with an elevation of 620 m. The annual rainfall is 1,800–2,500 mm (Figure 1). The daily temperature fluctuates between 22 and 32 °C, with a little variation throughout the year. The annual humidity ranges from 65 to 90% during the rainy season. The soil type is alfisol (Oxic-Tropudalf – USDA soil taxonomy or Ferruvic – FAO/UNESCO), well-drained with moderate fertility [37].

Catimor Coffea, a branch of *Coffea arabica* species, is planted with a density of 4,200 trees/ha with a spacing of 2 × 1.2 m. The coffee farms were established in 2008 and have produced raw coffees for seven years. The average production of the farms is 10.3 tons of raw coffee/ha/year. Fertilizing and weeding are the techniques applied for tree nurturing. The trees are not watered.

Machilus odoratissima Nees is a native species with a high economic and environmental value. The bark of this species is used to make incense sticks, bio-glue, and used in medicine. This study evaluates and compares the model of inter-planting cultivation (*Coffea arabica* and *Machilus odoratissima*) with mono cultivation (only coffee trees). The studied *Machilus odoratissima* trees are eight years old and are purposively planted in rows to protect the coffee trees. The density of planting *Machilus odoratassima* is 800 trees/ha, and its average height is 7.8 m.

2.2 Data collections

Surveying the ecological characteristics

The wind speed behind the row of *Machilus odoratissima* was measured in September 2018, when the wind was strongest, and the rainfall was highest. Twelve anemometers were used to measure the wind at a 2-metre height. The anemometers were spotted at six locations in each model: 3 m in the front and 3, 6, 9, 12, and 15 m behind the *Machilus* rows (denoted Point 1, Point 2, Point 3, Point 4, Point 5, and Point 6, respectively). The wind speed was measured daily from 14:00 to 15:00 every five minutes for both models.

A handheld hygrometer and thermometer were used to measure the soil's moisture and temperature at a 7–10 cm depth. The data were collected daily from 13:00 to 13:30 in May 2018, when the drought was worst in the year. The measurements were conducted in thirty evenly distributed locations.

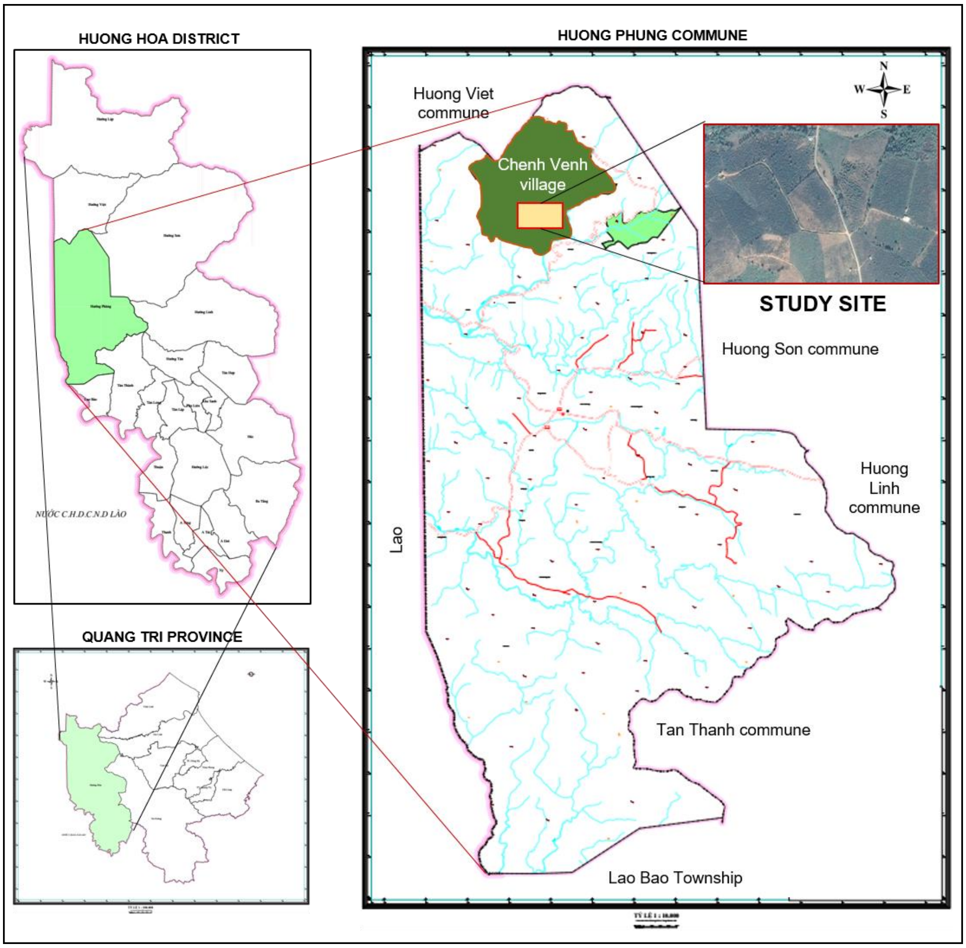

Figure 1. Location map of study area

Coffee yield

The raw coffee yield in both models was calculated according to the average household production on a hectare harvested at the end of November 2018.

In both models, household interviews were also adopted to investigate the total cost and income of a hectare of coffee plantations to evaluate the profits. Twenty households in the models were interviewed.

2.3 Statistical analysis

The Net Present Value (NPV) indicator was adopted to evaluate economic efficiency. The trading rotation of coffee was seven years (to match that of *Machilus*). From this indicator, the sustainability and efficiency of the models were evaluated.

3 Results and discussions

3.1 Wind speed in *Coffea* farms

The wind is an environmental factor that significantly affects the ability of fruiting or preventing fruit from dropping off the coffee trees. The data of wind speed collected at different locations of the two models are presented in Table 1.

The result shows that there is a significant change in wind speed at the inter-planting (*Coffea* – *Machilus*) farms. The wind speed at Point 6 (15 m behind the *Machilus* rows) reduced by 40.41% compared with the wind speed in front of the *Machilus* rows (Point 1), from 3.91 to 1.58 $m \cdot s^{-1}$. By contrast, no noticeable change in wind speed was detected at the mono-planting farm; it slightly varied from 3.81 to 3.93 $m \cdot s^{-1}$. The reduction of wind speed proved the effective contribution of *Machilus* trees in positively changing the surrounding environment [27, 38, 43], hence creating advantageous conditions for the growth and reducing fruit dropping of the coffee trees [22, 26].

Figure 2 presents the wind speed through the coffee farms in the two models (mono-planting and inter-planting).

Table 1. Wind speed through coffee farms in the two models

Coffee farming mode	Wind speed at each location ($m \cdot s^{-1}$)					
	Point 1	***Point 2***	***Point 3***	***Point 4***	***Point 5***	***Point 6***
Coffea inter-planting with *Machilus*	3.91	3.25	3.01	2.41	1.89	1.58
Coffea mono-planting	3.87	3.91	3.93	3.86	3.81	3.85

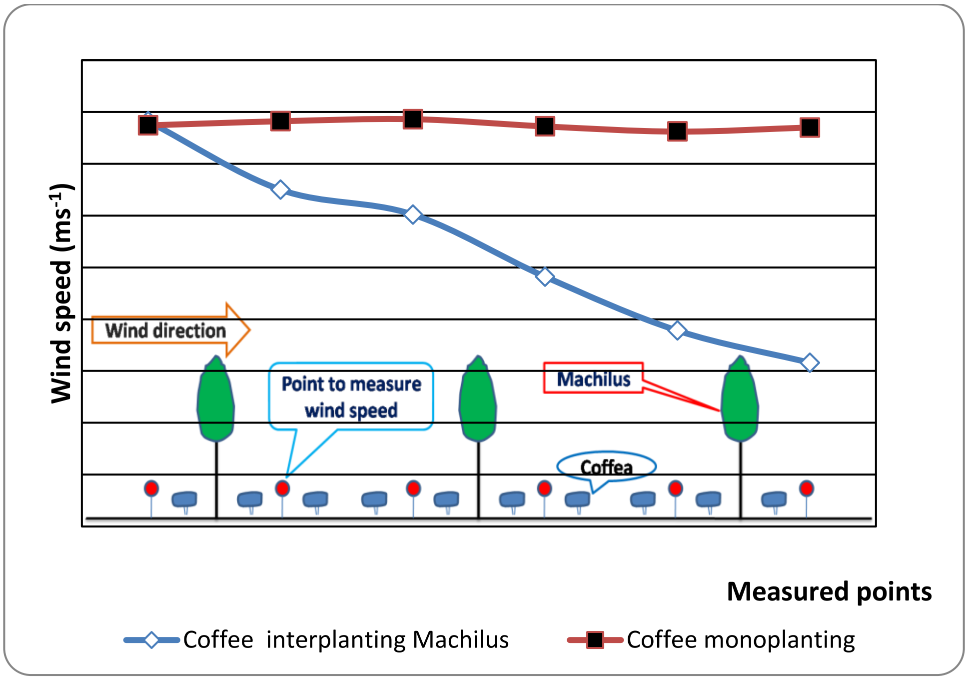

Figure 2. Wind speed through farms of coffee mono-planting and coffee inter-planting *Coffea – Machilus* in September, 2018

3.2 Changes in soil temperature and moisture

Under the canopy of the *Machilus* with an average diameter of 2.9 m and shading level of 0.4, the illumination absorbed by coffee trees decreases. This illumination ecologically plays a vital role in the coffee tree growth, and numerous researchers report that the coffee trees grow better in the shadow [11, 30]. In most countries, the inter-planting model (coffee tree and shading-tree, in this case, the model is *Coffea* and *Machilus*) has been largely adopted, and its ecological efficiency (especially, soil temperature and soil moisture) has been proven [1, 3, 4, 7, 8, 24, 33, 39, 40, 43].

The results related to soil temperature and soil moisture of the mono-planting model and inter-planting model are presented in Table 2.

Table 2. Soil temperature and soil moisture collected at the two models and its changes

Coffee farming mode	Soil temperature (°C)		Soil moisture (%)	
	Value	*Against Coffea mono-planting*	*Value*	*Against Coffea mono-planting*
Coffea mono-planting	28.3	–	23.4	–
Coffea inter-planting *Machilus*	24.7	–3.6	28.5	5.1

3.3 Coffee yield and dropping rate

With inter-planting the *Machilus* trees, ecological conditions are significantly improved for the growth of the coffee trees. Both quantity and quality of coffee beans increase with a 95% confidence level. The yield of coffee bean harvested in December 2018 and the amount of fallen-coffee fruits of both models are shown in Table 3.

3.4 Windbreak function (protecting coffee fruit from shading)

The coffee yield of the inter-planting model harvested in 2018 was 10.12 tons/ha, 0.74 tons/ha higher than that of the mono-planting model (9.38 tons/ha). The quantity of premature fruit dropping in the mono-planting and inter-planting models was 0.26 and 0.12 tons/ha. In general, there is a noticeable improvement in the coffee yield due to a significant reduction of dropped fruits in the model of inter-planting *Coffea* and *Machilus* compared with that of the mono-planting model.

Machilus odoratissima creates suitable ecological conditions for the growth of coffee trees. Reducing the temperature and increasing the moisture of cultivated soil in harsh weather (drought and no watering) are the benefits of *Machilus* trees, and as a result, the coffee trees grow better [6, 44]. Coffee ripens from August to October, and these months are also the season of heavy rain and storm, which cause fruit dropping. With a windbreak function of the *Machilus* trees, the coffee fruit dropping decreases significantly, and, therefore, the coffee yield increases.

3.5 Sustainable income

The economic efficiency of the two models in 2018 is presented in Table 4. The yield of the inter-planting model (*Coffea* and *Machilus*) is 10.12 tons•ha^{-1}•year^{-1}, 7.5% higher than that of the mono-planting model. Regarding the economic effect generated by coffee trees, no significant difference between the two models is observed. However, in comparison with the total profit of the mono-planting model (2,352.61 USD/year/ha), the inter-planting model exhibits a 35.83% increase (3,195.61 USD/year/ha). This increase significantly contributes to the household income, and the economic efficiency of the inter-planting model is proven correspondingly.

Table 3. Comparison of coffee yield and weight of fallen coffee fruits between two coffee farming models

Coffee farming mode	**Coffee yield (ton·ha^{-1})**		**Weight of fallen coffee fruits (ton·ha^{-1})**	
	Yield	***Against coffea mono-planting***	***Weight***	***Against coffea mono-planting***
Coffea mono-planting	9.38	–	0.26	–
Coffea inter-planting *Machilus*	10.12	0.74	0.12	–0.14

Table 4. The economic efficiency of the mono-planting and inter-planting models

Coffee farming mode	Productivity (ton·ha^{-1})	Revenue (USD·ha^{-1})	Profits (USD·ha^{-1})	Increased versus mono-planting (%)
Coffea mono-planting	9.38	3,874.35	2,352.61	–
Coffea inter-planting *Machilus*		4,717.39	3,195.65	35.83
Coffea	10.12	4,180.00		
Machilus	2.06	537.39		

The income from the *Machilus* trees increases the coffee farms' productivity and financially supports the coffee-planting farmers when the coffee price drops or the coffee yield reduces due to harsh weather. In most countries where the coffee trees are mono-cultivated, the farmers face various risks from natural disasters to market fluctuation. This challenge causes the farmers to destroy the coffee trees and plant other trees instead [12, 20, 25]. It should be noted that *Coffea* is an industrial and perennial crop, and it takes a long time to establish and needs a significant investment for intensive cultivation [14, 32]. This creates difficulties to the farmers regarding their farming and livelihood.

3.6 Improving ecological environment by carbon fixation ability of *Machilus* trees

According to Huy [18], the carbon fixation of *Machilus odoratissima* in an agroforestry model fluctuates from 25 to 84 tons/ha. With an average density of 650 trees/ha, the current study shows a significant contribution of *Machilus* trees in carbon fixation where 8.3 to 28.0 tons of carbon is fixed, equivalent to 130.43–434.78 USD per hectare.

In addition, the ability to fix carbon dioxide of *Machilus* trees in the *Coffea* and *Machilus* inter-planting model is also environmentally significant because it has been reported to diminish the greenhouse effect causing climate change globally [15].

4 Conclusions and recommendations

In the circumstance of climate change and market fluctuation occuring in Quang Tri province, Vietnam, the *Coffea* and *Machilus* inter-planting model effectively contributes to the coffee farms' growth, productivity, and sustainability.

It should be noted that the comparison of the effects of the two models is based on the currently existing farms established by local farmers; therefore, several ecological factors are not specified and assessed. It is necessary to conduct further research dealing with these conditions more systematically and comprehensively.

References

1. Alemu M. M. (2015), Effect of Tree Shade on Coffee Crop Production, *Journal of Sustainable Development*, 8(9), URL: http://dx.doi.org/10.5539/jsd.v8n9p66.
2. Ayoola, J. B., Ayoola, G. B. and Ladele, A. A. (2012), An assessment of fators constraining coffee production and marketing in Nigeria, *I. J. S. N.*, 3(3), 678–683.
3. Baggio A. J., Caramori P. H., Adrocioli Filho A. and Montoya L. (1997), Productivity of Southern Brazilian coffee plantations shaded by different stocking of Grevillea robusta, *Agroforestry Systems*, 37, 111–120.
4. Beer J., Muschler R., Kass D., and Somarriba E. (1998), Shade management in coffee and cacao plantations, *Agroforestry system*, 38, 139–164.
5. Bisang B. W., Jansen D., Linne K., Thiet N., Walz H. (2016), Climate Change and Vietnamese Coffee Production – Training Manual, Manual on climate change adaptation and mitigation in the coffee sector for local trainers and coffee farmers, Training manual, 46 pp.
6. Boreux V., Kushalappa C. G., Vaast P., and Ghazoul J. (2012), Interactive effects among ecosystem services and management practices on crop production: Pollination in coffee agroforestry systems. www.pnas.org/cgi/doi/10.1073/pnas.1210590110.
7. Bosselmann A. S., Dons K., Oberthur T., Olsen C. S., Ræbild A., Usma H. (2009), The influence of shade trees on coffee quality in small holder coffee agroforestry systems in Southern Colombia, *Agriculture, Ecosystems and Environment*, 129, 253–260.
8. Bote A. D. and Struik P. C. (2011), Effects of shade on growth, production and quality of coffee (*Coffea arabica*) in Ethiopia, *Journal of Horticulture and Forestry*, 3(11), 336–341.
9. Cuc N. S. (2009), Development of perennial plants in Vietnam: Issues and solutions. *Journal of Economic Management*, 24, 66–72.
10. Cuong P. (2015), Evaluation of current planted areas and economic efficiency of *Machilus odoratissima* Nees plantation in Huong Hoa district, Quang Tri province, Vietnam, *Journal of Agriculture and Rural Development*, Volume 12/2015, 112–120.
11. DaMatta F. M., Ronchi C. P., Moacyr Maestri1 and Barros R. S. (2008), Ecophysiology of coffee growth and production. *Braz. J. Plant Physiol.*, 19(4), 485–510.
12. Gathura M. N. (2013), Factors affecting Small-Scale Coffee Production in Githunguri District, Kenya, *International Journal of Academic Research in Business and Social Sciences*, 3, 9.
13. Haggar J. and Schepp K. (2012), Coffee and Climate Change, Impacts and options for adaption in Brazil, Guatemala, Tanzania and Vietnam.

14. Haggar J. (2011), Coffee and Climate Change, Desk Study: Impacts of Climate Change in the Pilot Country Tanzania of the Coffee & Climate Initiative.

15. Hergoualc'h K., Blanchart E., Skiba U., Hénault C. and Harmand J. M. (2012), Changes in carbon stock and greenhouse gas balance in a coffee (Coffea arabica) monoculture versus an agroforestry system with Inga densiflora, in Costa Rica, *Agriculture, Ecosystems and Environment*, 148, 102–110.

16. Ho P. H. (1999), An illustrated flora of Vietnam, Young Publisher, Hanoi Branch, year 1999, 396.

17. Huong N. and Ward M. (2015), Vietnam coffee annual, GAIN report number: VM5030.

18. Huy B. (2009), Estimating CO_2 absorption capacity of *Litsea glutinosa* in the agroforestry model with Litsea – Cassava in Mang Yang district, Gia Lai province – Highlands, Vietnam.

19. Jassogne L., Laderach P. and Asten P. V (2013), The Impact of Climate Change on Coffee in Uganda. Lessons from a case study in the Rwenzori Mountains, Oxfarm Research Report.

20. Kalyebara R. (1999), A comparison of factors affecting adoption of improved coffee management recommendations between small and larger farmers in Uganda, *CIAT International Workshop: Assessing the Impact of Agricultural Research on Poverty Alleviation, San Jose, Costa Rica;* 14–16.

21. Kavya S. K. (2013), A Study on the Impact of Climate Change on the Productivity and Women Employment in Coffee and Tea Plantations in India, *International Journal of Science and Research (IJSR).*

22. Kufa T. and Burkhardt M. J. (2011), Plant composition and growth of wild Coffea arabica: Implication for management and conservation of natural forest resources, *International Journal of Biodiversity and Conservation*, 3(4), 131–141.

23. Loi D. T. (2004), *Vietnamese medicinal plants*, Medical Publisher, Hanoi, 539.

24. López-Bravo D.F., Virginio-Filho E. M., Avelino J. (2012), Shade is conducive to coffee rust as compared to full sun exposure under standardized fruit load conditions, *Elsevier - Crop Protection*, 38, 21–29.

25. Lugado C. and Omukoko C. (2017), Factors leading to decline of coffee in Vihiga County, Kenya, *Asian Journal of Agricultural Extension, Economics & Sociology,* 16(4), 1–5*; Article no.AJAEES.32808*.

26. Lum J., Baker K. and Baumann D. (2016), Technical Specification Coffee Agroforestry: From Rust to Resilience.

27. Marsh A. (2007), Diversification by smallholder farmers: Viet Nam Robusta Coffee, Agricultural management, marketing and finance working document, FAO 2007.

28. Minai, J. M., Nyairo, N. and Mbataru, P. (2014), Analysis of socio-economic factors affecting the coffee yields of smallholder farmers in Kirinyaga County, Kenya. *Journal of Agricultural and Crop Research*, 2(12), 228–235.

29. Nath C. D., Pelissier R., Ramesh B. R., and Garcia C. (2011), Promoting native trees in shade coffee plantations of southern India: comparison of growth rates with the exotic Grevillea robusta, Agroforest System. DOI 10.1007/s10457-011-9401-8.

30. Nchare A., (2007), Analysis of factors affecting technical efficiency of Arabica coffee producers in Cameroon, *AERC research papers*, 163, 38.

31. Nsibirwa R. W. (2010), Coffee Yield [Productivity] and Production in Uganda: Is it Only a Function of GAP and Diseases?

32. Perfecto I. and Vandermeer J., (2008), Partial pattern and ecological process in the coffee agroforestry system, *Ecology*, 89(4), 915–920.

33. Perfecto I., Armbrecht I., Philpott S. M., Soto-Pinto L. and Dietsch T. V. (2007), Shaded coffee and the stability of rainforest margins in Northern Latin America, Springer Verlag Berlin, 227–263.

34. Phan M. G., Phan T. S., Matsunami K. and Otsuka H. (2006), New neolignans and lignans from Vietnamese medicinal plan *Machilus odoratissima* Nees, *Chem Pharm Bull* (Tokyo), 54(3), 380–3.

35. Quan T. (2016), Vietnam coffee annual, GAIN report number: VM6033.

36. Quan T. (2017), Vietnam coffee annual, GAIN report number: VM7024.

37. Quang Tri province (2019), Statistical Yearbook 2019.

38. Rising J., Foreman T., Simmons J., Brahm M. and Sachs J. (2016), The impacts of climate change on coffee: trouble brewing.

39. Souza H. N., Goede R. G. M., Brussaard L., Cardoso I. M., Duarte E. M. G., Raphael B. A. Fernandes, Gomes L. C. and Pulleman M. M. (2012), Protective shade, tree diversity and soil properties in coffee agroforestry systems in the Atlantic Rainforest biome, *Agriculture, Ecosystems and Environment*, 146, 179–196.

40. Srishnan S. (2017), Sustainable coffee production. DOI: 10.1093/acrefore/9780199389414.013.224.

41. Trinh P. T., Thu D. C. and Tien T. M. (2014), Economic Efficiency of Macadamia and Coffee Intercropping on Basaltic Soils in Krong Nang District, Dak Lak Province. *J. Sci. & Devel.*, 12(3), 422–428.

42. United States Department of Agriculture (2017), Coffee: World markets and trade, Foreign Agricultural Service.

43. Vaast P., Bertrand B., Perriot J. J., Guyot B. and Genard M. (2006), Fruit thinning and shade improve bean characteristics and beverage quality of coffee (Coffea arabica L.) under optimal conditions, *J. Sc.i Food Agric.*, 86, 197–204. DOI: 10.1002/jsfa.2338.

44. Vergara C. H. and Badano E. I. (2008), Pollinator diversity increases fruit production in Mexican coffee plantations: The importance of rustic management systems, Agric Ecosyst Environ, doi:10.1016/j.agee.2008.08.001.

45. Verkooijen L., Ruiz A. G. and Fobelets V. (2016), The true price of coffee from Vietnam. Joint report by IDH and True Price.

46. Whelan T., President and Newsom D. (2014), Sustainable coffee farming. Improving income and social conditions protecting water, soil and forests.