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PAPUA NEW GUINEA

DISCUSSION PAPER

DETERMINANTS OF COFFEE PRODUCTION IN MAJOR COFFEE-PRODUCING PROVINCES OF PAPUA NEW GUINEA: CHALLENGES AND OPPORTUNITIES

Eugene E. Ezebilo
Carolyn A. Afolami

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Authors' Contributions

Associate Professor Eugene Ezebilo conceived and designed the project, designed the final data collection instrument. He prepared the data for analysis, conducted qualitative analysis, descriptive statistics, estimated the Ordinary Least Squares regression models. He wrote the discussion, conclusion and abstract sections of the manuscript and he also wrote the first version of the results section. Professor Carolyn Afolami wrote the first version of the introduction, literature review, materials and method sections. Associate Professor Ezebilo and Professor Afolami contributed in the revision of all sections of the manusucript.

Abbreviations and Acronyms

CBB	Coffee Berry Borer
CIC	Coffee Industry Corporation
CLR	Coffee Leaf Rust
EHP	Eastern Highlands Province
GoPNG	Government of Papua New Guinea
ICO	International Coffee Organisation
kg	Kilogram
MP	Morobe Province
OLS	Ordinary Least Squares
PPAP	Productive Partnerships in Agriculture Project
PNG	Papua New Guinea
QCA	Qualitative Content Analysis
SCGA	Smallholder Coffee Growers Association
WHP	Western Highlands Province

Abstract

Coffee has the potential to provide income for households and government revenue. However, some coffee-producing countries have continued to witness a decline in the quantity of coffee produced. This paper reports a study which examined the farm and coffee grower's characteristics influencing the quantity of coffee producd. It also examined the challenges and opportunities in coffee production. The data was obtained from interviews with coffee growers in Eastern Highlands, Morobe and Western Highlands provinces and was analysed using qualitative content analysis, descriptive statistics and Ordinary Least Squares (OLS) regression model. The results showed that an average of 42 of 60kg bags of coffee were produced annually, the average age of trees on the coffee plots was 21 years and only a few interviewees (21%) received extension services annually. The most important challenges of coffee production include coffee leaf rust, coffee berry borer, poor extension services and poor access to markets and processing facilities. The OLS results showed that the most important factors influencing the quantity of coffee produced include the location of coffee plot, labour type, coffee production scale and access to productive partnership in agriculture project, educational level, awareness of the productive age of coffee tree and participation in coffee production training. The available opportunities in coffee production in Papua New Guinea (PNG) include availability of conducive environment and coffee plantations that can be revitalised. The findings provide an input into the discussion regarding the potential ways to improve coffee production so that coffee can contribute more to PNG economy and to households income.

Introduction

Coffee is one of the most important agricultural commodities that are traded and consumed in several countries and it provides income to households and revenue for governments in most coffee-producing countries (Panhuysen and Pierrot, 2018; Rahn et al., 2018). In most coffee-producing countries, increasing yields of coffee alleviate the pressure to expand the amount of planted land and allow farmers to improve their livelihoods based on existing land use (Treanor and Saunders, 2021). According to the International Coffee Organization (ICO) (2021), 169.6 million 60kg bags of coffee was produced worldwide in 2020, of which, top 10 coffee-producing countries accounted for 89.2 percent. For instance, Brazil contributed 37.4 percent and Vietnam, Colombia and Indonesia contributed 17.1 percent, 8.4 percent and 7.1 percent respectively. Papua New Guinea (PNG), which is the focus of the study reported in this paper, contributed 0.5 percent to the world's coffee production and ranked 18th in 2020.

Coffee production in PNG provides opportunities for employment and foreign exchange earnings (Afolami and Ezebilo, 2021). The country grows mostly Arabica (94 percent) and Robusta (6 percent) of the total production (Ezebilo, 2021). Commercial coffee production in the world is based on two species: Coffea *Arabica* (Arabica) and Coffea robusta or Robusta (Winston et al., 2005). The market price of Arabica is often higher than that of Robusta because it produces coffee bean of higher quality compared to that of Robusta. However, Robusta is more resistant to diseases than Arabica. According to Afolami and Ezebilo (2021), PNG has suitable environmental and climatic conditions for growing high quality coffee and the country has the potential to be one of the top coffee-producing countries in the world. However, the total production of coffee in PNG in 2019/2020 season declined by 45 percent compared to the 1999/2000 (ICO, 2021). In fact, apart from 2011/2012 coffee season, (1,414 thousand 60kg bags), production in other seasons from 1999 to 2020 has not been able to match the production of 1999/2000 season (1,387 thousand 60kg bags).

Coffee is a cash crop that contributes to the PNG economy through revenue from taxes and it contributes to livelihoods of people who depend on coffee enterprises directly or indirectly for income (Afolami and Ezebilo, 2021). As a decline in coffee production results in a decrease in government revenue and a decrease in income for people who depend on coffee enterprises for income, there is a need to find the reason for the decline in production and how to boost coffee production in PNG. A clear strategy for PNG's coffee industry is needed to reorient the nation to pursue its comparative advantages. The study reported in this paper contributes to it by finding the determinants of coffee production, challenges that coffee production faces and potential ways to address the challenges in three coffee-producing provinces (Eastern Highlands, Western Highlands and Morobe). Several authors have published papers that focus on coffee production in PNG such as Overfield (1998), who found that poor relative labour returns for women influence the level of household success in cultivating coffee. Coelli and Fleming (2004) in their study of diversification economies found that diversification economies were weak between subsistence food production and both coffee and cash food production. Sengere et al. (2019) found that collective action and partnership with farmer groups (cooperatives) can improve coffee production and quality.

Eves and Titus (2017) found that though coffee production has been promoted as men's business or planted on their lands in Eastern Highlands Province, it does not prevent women from being involved in its production. In a study of factors that affect coffee production and export supply Aba et al. (2012), found that the development in international price of coffee does not have influence on production and export supply of coffee. Trade weighted income levels of major coffee partners have a long-run effect on coffee production and export supply. They also found that during election period, coffee production and export declines. Low adoption rate of new technologies by farmers in coffee industry is due to the fact that most smallholder cash crop farmers in PNG are risk averse and utilise a low labour input system of production leading to very low productivity levels, relative to plantation levels (Omuru et al., 2001; Api et al., 2009). World Bank (2009) reported that lack of tailored extension packages and poor market access that reduce farm-gate prices are linked to the low productivity in coffee production.

Altman et al. (2020) found in their study of productivity of coffee farmers' cooperatives in Eastern Highlands Province that economies of scale exist in moderate-sized coffee cooperatives and that low productivity in cooperatives can be

addressed through organisational change. Using secondary data collected from Food and Agriculture Organisation Statistics, International Coffee Organisation and World Bank, Afolami and Ezebilo (2021) examined strategy for improving coffee production in PNG by drawing lessons from top five coffee-producing countries. They found that coffee growers, especially smallholders do not have access to extension services and that from 1998 to 2018, the coffee area harvested in PNG and the quantity of coffee produced declined.

To the best of our knowledge, there is no published paper on coffee production in PNG that have focused on farm attributes and coffee growers' attributes determinants of coffee production in several coffee-producing provinces and the challenges that coffee growers face in producing coffee. We are not also aware of any published paper in PNG, which considered the three coffee grower owner categories (plantation, coffee block and smallholder). The study reported in this paper tend to fill the knowledge gap by examining both farm and coffee growers' attributes that influence coffee production, challenges coffee growers face in three top coffee-producing provinces.

Objectives of the study

The main objective of this study is to assess the pathways of improving the revenue potential of coffee to boost PNG economy and to sustain livelihoods of households who depend on coffee for income. Using three major coffee-producing provinces (Eastern Highlands, Morobe and Western Highlands) in PNG as case study areas, the specific objectives of this study are the following:

1. To examine farm and coffee growers' attributes in relation to three major coffee-producing provinces and to determine factors influencing coffee production.
2. To identify challenges and opportunities associated with coffee production and to find potential strategy to address the challenges.

Findings from the study will assist agriculture managers and planners in developing a strategy for boosting coffee production in PNG especially in terms of addressing challenges that restrict coffee growers from expanding or maintaining production.

Structure of the paper

The introductory section is followed by a section on the review of literature on the subject, challenges associated with coffee production, how challenges have been addressed in other parts of the world and coffee production opportunities in Papua New Guinea. These are followed by materials and methods, results and discussion. The last section is conclusions.

Literature Review

This section reviews literature on factors influencing coffee production, challenges of coffee production and possible pathways to overcome such challenges.

Review on determinants of coffee production

Literature has shown that coffee output is falling in some countries (Baker, 2014). According to Taye (2010), the use of local coffee varieties and the use of traditional coffee production and processing practices have adverse effect on coffee production and productivity of smallholder coffee growers in Ethiopia. Piato et al. (2020) found that the productivity of coffee plantations are threatened by climate change and the decreasing revenue of coffee growers. Rising environmental temperature may render some coffee-producing areas less suitable or even completely unsuitable for coffee growing (The International Trade Centre, 2010). Craparo et al. (2015) and Jayakumar et al. (2017) found that, an increase in environmental temperature in Tanzania and India is linked to the decline in the production of Arabica coffee. However, Robusta coffee may respond better to increasing temperatures than Arabica coffee (Kath et al. 2020). Pests and diseases are a challenge for coffee growers and some may cause more damage to coffee with climate change (Lambot et al., 2017). Vaast et al. (2006) found that shade increased bean size and improved Arabica cup quality in the central valley of Costa Rica. However, in a southern Colombia study, Bosselmann et al. (2009) found that shade had a negative impact on cup quality of Arabica coffee, but did not affect bean size.

In an Ethiopian study of factors influencing coffee quality, Deribe (2019) found that timing of farm operations, postharvest processing techniques, grading, packing, storage conditions influence coffee quality. In a Indonesian study, Rahmanta and Supriana (2019) found that low productivity of Arabica coffee is caused by the suboptimal use of production factors such as the number of plant population per unit of planting area, the presence of old coffee plants that are less productive, the dosage and amount of fertiliser used that are not in accordance with the recommended, the use of labour that has not been efficient and effective, and the use of pesticides that are not in accordance with recommended doses.

According to Karanja and Nyoro (2002), low coffee production in Kenya results from the fluctuation in international market prices, which saw Kenya reduce annual production of 130,000 metric tonnes of clean cherry in 1987/88 to 50,000 metric tonnes. In a Kenyan study of determinants of coffee production, Mugweru (2011) found that there is a positive relationship between price and coffee output. Maundu and Karugu (2018) found that access to credit and cost of production in Kenya have a positive and significance effect on production of coffee among the smallholder farmers. In a Rwandan study of factors influencing small-scale coffee farmers, Mukashema et al. (2016) found that factors such as demography and environmental factors like climate, soil and topography influence coffee production. In an Ethiopian study of factors impacting on coffee production, Bekele and Guadie (2020) found that types of coffee, farmers' total income and farm size determine coffee production. In a Nigerian study of the constraints associated with the production and marketing of coffee, Ayoola et al. (2012) found that the constraints include lack of capital, poor market information, and poor market network, pests and diseases, fire outbreak, and drought, lack of access to farm credit and inefficient extension service. Nchare (2007) found in a Cameroonian study of factors influencing technical efficiency of Arabica coffee farmers that the educational level of the farmers and access to credit are the major socioeconomic variables influencing the farmers' technical efficiency. Coffee productivity gains can be realised by improving technical efficiency.

According to Trevisan (2018) and Folnovic (2020), coffee production is determined by climatic conditions, pests and diseases, market prices, technology, labour and finance. Tolera and Gabermedia (2015) found in an Ethiopian study that diseases, pests, poor access to market information, lack of improved coffee variety and weak extension services constrain coffee production. Extension contact influences farmer households' adoption of techniques to improve production (Nkoya et al., 1997). Several studies suggest that membership in cooperatives improves the commercialisation behaviour of the productivity of farmers, which in turn enhances farmer security and allocative efficiency (Abate et al., 2014). Cooperative contributes to reduce transaction costs and information asymmetry by

strengthening members' ability (Trebbin, 2014). Balgah (2019) found that area of land under coffee cultivation, dominant income source, experience in coffee farming influence farmer's decision to join cooperative.

Challenges associated with coffee production

Coffee industry has experienced various challenges, among which low production is one of the most crucial problems encountered directly by smallholder farmers. These constraints have generated low yields that pose challenges to small-scale farmers' livelihoods. Researchers and coffee farmers often perceive pests and diseases as the primary factor that contributes to the low yield in coffee production. Coffee wilt disease and coffee berry borer lead to poor quality output (UCDA, 2012). Jima et al. (2017) reported that the most economically important coffee pests and diseases are coffee berry borer disease, coffee wilt disease and coffee leaf rust.

A study by Theuri (2012) investigated challenges affecting revitalisation of coffee, which included access to coffee market, funding of coffee, management of coffee cooperative societies and gender issues influencing coffee revitalisation programme in Mukurweini district in Kenya. It has been shown that declining productivity of coffee is partly due to low use of inputs, marketing problems, poor governance of cooperatives and international marketing conditions (Theuri, 2012).

Some ways that challenges associated with coffee production has been addressed

There are a number of coffee-producing countries that have applied various regulatory measures to benefit their national coffee sector (ICO, 2019). For instance, Costa Rica and Colombia heavily manage their coffee sectors in the sense that they establish strict boundaries within which market forces can work.

A review of Vietnam's Nationally Determined Contribution (NDC) identified the intercropping of coffee and avocados as incurring the lowest marginal cost of a number of potential scenarios to reduce land-based emissions (Carbonari et al., 2019). In another study, intercropping of coffee and macauba (a native palm species) in Brazil provided both increased coffee productivity and a climate mitigation strategy (Moreira et al., 2018).

A supply management measure considered by ICO as a response to the low coffee price levels in the early 2000s was the diversion of coffee below a certain minimum standard to alternative uses, such as animal feed, briquetted fuel, mulch and biogas (ICO, 2011). Development of a new generation of coffee farming professionals within PNG by improving the image and attractiveness of coffee as an international agribusiness, developing new events and activities that incorporate youth engagement in the coffee sector, and sponsoring internship programs for students interested to pursue a career in farming are some ways to promote coffee (FAO, 2014).

de Almeida and Zylbersztajn (2017) has identified the following as ways to overcome some challenges facing coffee production:

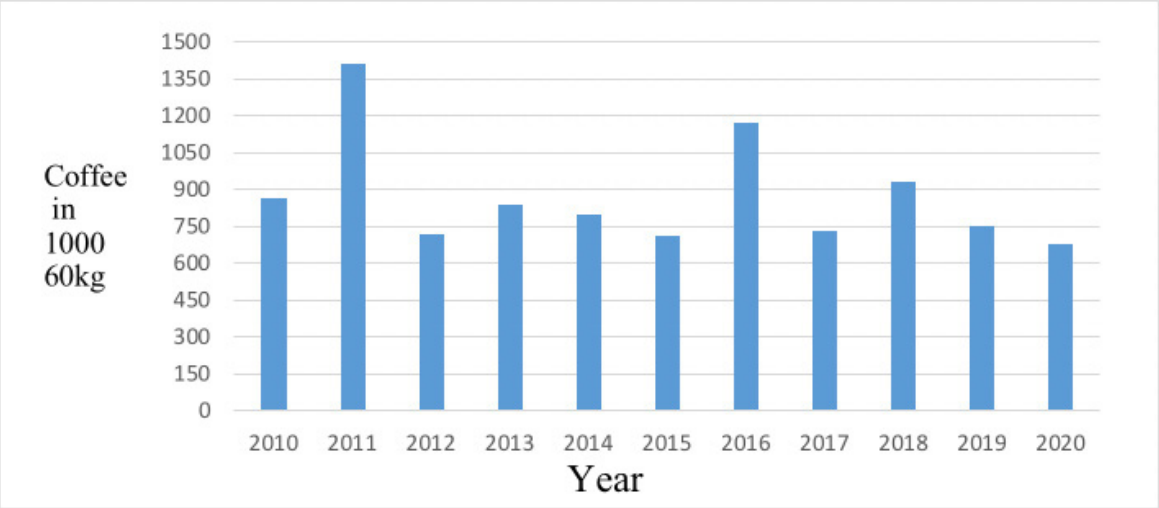
(i) Provide incentive loyalty to the farmer in order to guarantee high-quality coffee supply through formal or informal contracts, (ii) increase entry barriers to ensure the maintenance of leadership in world coffee production and exportation, (iii) operational risk minimisation for companies as well as coffee farmers, (iv) encouragement and participation in the farmers' actions to make coffee activity more environmentally friendly, and (v) designing marketing plans connected with the coffee consumers' habits and desires.

Material and Methods

Coffee is grown in commercial quantity in 15 of the 22 provinces of PNG. Arabica, which is suitable to areas located in high altitudes are grown in the Highlands region of the country. Robusta are often cultivated in coastal areas with low elevations such as Southern region, New Guinea Island region and Momase region. However, some areas in the Momase region that have boundary with the Highlands region such as Morobe Province, Arabica may be grown there.

In terms of total volume of coffee production in PNG, it ranges from 675 thousand 60kg bags in 2020 to 1,414 thousand 60kg bags (Figure 1).

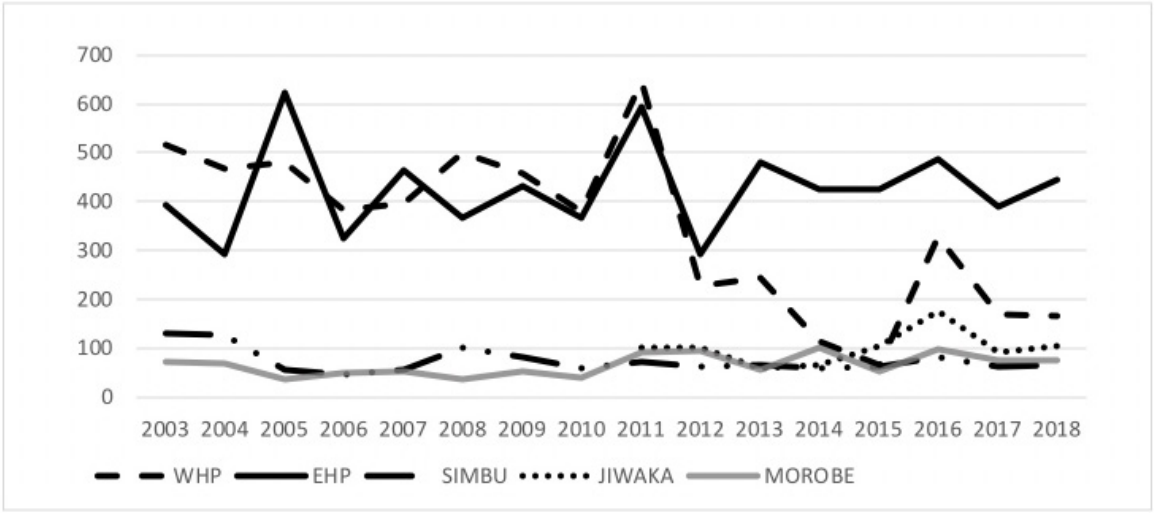
Figure 1. Total coffee production in thousand 60kg bag



Data source: International Coffee Organisation, 2021.

In terms of production volume, the most important five provinces are Eastern Highlands (EHP), Western Highlands (WHP), Simbu, Morobe and Jiwaka (CIC, 2016). Of the five provinces, WHP have been leading the provinces before the creation of Jiwaka in 2012, which was carved out from WHP (Figure 2). For instance, coffee production in the province ranged from 334,645 of 60kg bags in 2006 to 645,312 of 60kg bags in 2011. However, EHP have been leading since 2012, its production ranges from 292,898 of 60kg bags in 2012 to 487,626 of 60kg bags in 2016.

Figure 2. Coffee production in the top five PNG's coffee-producing provinces in thousand 60kg bag



Data source: Coffee Industry Corporation (CIC), 2019.

In PNG, coffee growers can be classified into the following three groups in terms of hectrage cultivated (CIC, 2016):

- Smallholders. These are coffee growers groups that use less than five hectares for coffee production. The group accounts for the majority of coffee growers. Smallholder coffee growers produce almost 95 percent of the total coffee produced in PNG.
- Coffee block. The group consists of coffee growers that use from five to 20 hectares for coffee production. Coffee block consist of customary land with freehold title secured under the Land Tenure Conversion scheme and issued to a communal business group. The size and membership of the group depend on land equity or cash contributions and it is typically supervised by management agencies.
- Plantation owners. These coffee growers group use more than 20 hectares for coffee production. According to CIC (2016), some of the plantations were previously owned by foreign settlers. However, Papua New Guineans who are mostly smallholders have taken over the plantations.

Production from coffee blocks and plantations contribute less than 20 percent of the total coffee production in PNG, which is a massive decrease from the quantity the two groups have been contributing in the past. The decline is as a result of land-related issues and coffee berry theft. Aba et al. (2012) reported that smallholder and block-holder coffee growers produce coffee to maintain their income and sustain their livelihoods. Plantation owners produce coffee for commercial purpose to maximise profit and add value to the shareholders.

In terms of government agency, which is in charge of the administration of coffee industry, CIC has the responsibility to provide leadership and services to the industry. It is empowered under the CIC statutory Powers and Functions Act 1991 (CIC, 2022). CIC was initially established as PNG Coffee Marketing Board in 1963 and it later became the Coffee Industry Board in 1976 and finally CIC in 1991. One of the CIC roles is to buy and sell coffee, set prices and monitor the export of coffee. However, CIC concentrates on its regulatory functions and leave marketing to private companies that are licensed by the corporation. CIC also has the responsibility of conducting research on coffee and in providing extension services and training to coffee growers.

The Productive Partnership in Agriculture Project (PPAP) is implemented to improve the livelihoods of smallholder coffee and cocoa producers through the improvement of performance and the sustainability of value chains in coffee- and cocoa-producing areas (Department of Agriculture and Livestock, 2022). The Project is implemented in collaboration with the World Bank, International Fund for Agriculture Development and Government of PNG (GoPNG). It involves the rehabilitation of market access especially rehabilitation of rural feeder roads and partnering with private sector value chain players to provide extension services to its farmers. The following provinces were selected for implementing PPAP:

Eastern Highlands Province, Western Highlands Province, Simbu Province, Morobe Province, East Sepik Province, Madang Province, and East New Britain Province.

Data Collection

Data was collected using interviews that were preceded by pilot survey. Questions used in the interviews were developed using literature reviews, expert opinion and pilot survey. First, literature reviews was conducted on the subject (i.e. factors influencing coffee production) to examine questions that have been used in the literature to study the determinants of coffee production and challenges associated with it. Second, following the literature reviews, some questions were drafted and revised several times before it was sent to two academics whose works were related to social aspects of agriculture in PNG and have conducted several surveys in the countries. Comments received from the academics were addressed and the questions draft revised and sent back to the academics. The process continued until the academics were satisfied with the questions. Third, following the approval of the questions draft by the two academics, the questions draft was used to conduct interviews with a small group (eight) of coffee growers (pilot survey) to explore whether the questions is easy to comprehend and whether there are some questions that need to be modified, to be added or excluded. Fourth, following the pilot survey, the questions draft was modified to address concerns raised by participants in the survey and final questions for the main survey was developed. The questions that were used for the main consists of 84 of which 30 of the questions was used in the

study reported in this paper. The survey questions that were used for writing this paper are presented in Box 1.

Box 1. Questions used in the study reported in this paper

i. Interviewee's gender
ii. Category of coffee grower that the interviewee belonged
iii. Number of years that the interviewee has engaged in growing coffee
iv. The variety of coffee the interviewee have on their coffee plot
v. The average of age of coffee trees on the interviewees' coffee plot
vi. The province that the interviewee has its coffee plot
vii. Whether the interviewee has replaced coffee trees with other crops on their coffee plot
viii. The quantity of coffee in 60kg bags that the interviewee produced in 2018, 2019 and 2020
ix. The number of times that the interviewee engaged in the pruning of coffee trees each year
x. Whether the interviewee has the problem of coffee leaf rust on his or her coffee plot
xi. If the interviewee has the problem of coffee leaf rust, how he or she has been managing it
xii. Whether the interviewee grows other types of crops on the same farm with coffee
xiii. Whether the interviewee has the problem of coffee berry borer on his or her coffee plot
xiv. If the interviewee has the problem of coffee berry borer, how he or she has been managing it
xv. Whether the interviewee is a member of a cooperative society
xvi. Whether the interviewee is a member of PNG Smallholders Coffee Growers Association
xvii. The type of labour that the interviewee has been using to harvest coffee cherries
xviii. The number of times that Extension Officers from Coffee Industry Corporation visited the interviewee each year
xix. The interviewee to suggest how extension services can be improved
xx. Whether the interviewee has received any form of training on either coffee production, processing or marketing in the last three years starting from 2018
xxi. Whether the interviewee is aware that coffee tree has it most productive age and that after that age yield begins to decline
xxii. The last time that the interviewee planted new coffee trees on his or her coffee plot
xxiii. Whether the interviewee has received coffee seedlings from Productive Partnership in Agriculture Project
xxiv. Educational level of the interviewee
xxv. Marital status of the interviewee
xxvi. Household size of the interviewee
xxvii. Age of the interviewee
xxviii. The income of the interviewee
xxix. The challenges that coffee growers face in processing their coffee and potential ways it can be addressed
xxx. The challenges that coffee growers face in marketing their coffee and potential ways it can be addressed

In terms of administering the survey, the study areas were selected using a multi-stage random technique. First,

all the provinces where coffee are grown in commercial quantity were identified. Second, the identified provinces were classified into four regions (Highlands, Momase, New Guinea Islands and Southern). Third, the regions were classified into the dominant coffee variety found there. This results into Highlands region for Arabica and other regions for Robusta. As Arabica and Highlands region account for the majority of the total quantity of coffee produced in PNG, two provinces were selected randomly from the seven provinces in the region. One province was selected from eight provinces in other regions. For the Highlands region, Eastern Highlands and Western Highlands provinces were selected and Morobe Province was selected from other regions corresponding to three provinces used as the study areas.

Twelve to 16 research assistants were recruited from each of the selected provinces and were trained for one day in survey administration. All the research assistants were undergraduate students of universities located in the study areas. Two researchers from the PNG National Research Institute coordinated the activities of the research assistants and were involved in data collection in collaboration with an official from the Division of Primary Industry or Department of Agriculture and Livestock in each of the study areas. The official of the Division of Primary Industry or Department of Agriculture and Livestock provided the team with information on areas where coffee growers were. The team visited the areas and coffee growers found in the areas were approached for interview using convenience sampling technique. Growers who accepted the interviews were interviewed. Some of the interviewees were asked to provide information on other areas where coffee growers can be found (snowball sampling technique). The team visited the areas and interviewed coffee growers who accepted to be interviewed. As there are several remote areas and areas with limited accessibility because of the poor road conditions, the team focused on only areas that they were able to access.

For the interviews, after introducing the subject, that is, assessment of coffee production, processing and marketing, the interviewee was asked a series of questions related to coffee growers categories they belonged and coffee plot characteristics. They were asked questions related to access to extension services, training, access to PPAP and about membership of cooperatives and PNG Smallholder Coffee Association. The interviewees were asked demographic questions such as educational level, income, household size, marital status and their age.

The interviews were conducted from July to September 2021 and a total of 510 coffee growers were interviewed. 113 coffee growers were interviewed in Morobe Province, 196 in WHP and 201 in EHP.

Data Analysis

Mixed method approach was used to analyse the data as a way to provide a holistic view of coffee production and challenges associated with it. The approach can assist us in having a clearer picture of the findings from the study as well as ensure that the findings are grounded in the interviewees' experiences (Venkatesh et al., 2013). The data was analysed using Qualitative Content Analysis (QCA), descriptive statistics and inferential statistics. The QCA was used to analyse open-ended questions such as challenges associated coffee processing and marketing that the interviewees face, potential ways on how they have coped with coffee the challenges. QCA involves systematic and objective means of describing and quantifying phenomena through coding, categorisation and identifying themes (Hsieh and Shannon 2005; Polit and Beck, 2008; Schreier 2012). We analysed the qualitative data using manifest analysis, which is a type of QCA that focuses primarily on the description of the actual responses of the interviewees (Berg, 2001). The analysis began by reading all the written responses on the challenges associated with processing and marketing of coffee, how the challenges were addressed and the coping strategy on coffee leaf rust infection and coffee berry borer infestation several times. The responses were then transcribed and the transcripts were read several times, followed by reading the responses again word by word and then summarised.

Regarding descriptive analysis, it was used to describe interviewees' and farm characteristics in relation to the province where data was collected (Eastern Highlands Province, Morobe Province and Western Highlands Province). The descriptive statistics was analysed using mean, percentages and standard deviation and were presented in graphical and tabular formats. For inferential statistics, it was used to examine the influence of socio-economic characteristics of interviewees and farm characteristics on the quantity of coffee produced. As the outcome variable (quantity of coffee produced) was continuous variable, Ordinary Least Squares (OLS) regression model was used to analyse the data.

The OLS regression model

One of the Gauss-Markov assumptions is that the variance of the error terms in OLS are equal, that is, homoscedasticity (Verbeek, 2007). To know whether the linear form of the OLS model meets the assumption, the Breusch-Pagan test (Greene, 2003) was conducted on the two models (FARM ATTRIBUTES model and FARMER ATTRIBUTES model) used in this study.

For the FARM ATTRIBUTES, the test statistic was 1154.43 and the critical chi-squared value was 26.22 at 12 degrees of freedom at 1 percent statistical significance level, we then rejected the null hypothesis of homoscedasticity. We also rejected the null hypothesis for the FARMER ATTRIBUTES because its test statistic (493.89) was higher than the critical chi-squared value at 11 degree of freedom at 1 percent (24.73). It indicates that the error terms of the OLS models did not have equal variance, that is, it is heteroscedastic. In order to correct for the heteroscedasticity, the log-linear form of OLS was applied. It entails the transformation of continuous variables in the model to log form. Thus, quantity of coffee produced and age of coffee trees were converted to logarithm using the LIMDEP statistical package for the FARM ATTRIBUTES model and was corrected using the White's heteroscedastically consistent variance estimator. For the FARMER ATTRIBUTES model, the quantity of coffee produced and the number of years of experience were transformed to logarithm and corrected with the White's heteroscedastically consistent variance estimator. We then conducted another set of Breusch-Pagan tests on the corrected models. The test statistic for the FARM ATTRIBUTES model reduced 33.57 and that of FARMERS ATTRIBUTES reduced to 11.59.

Farm characteristics and farmer's characteristics that might have influenced the quantity of coffee produced was estimated using two OLS models. The functional form for the FARM ATTRIBUTES model is the following (1):

$$Log(COFFEE_{prod}) = \beta_0 + \beta_1 Log(TREE\_AGE) + \beta_2 OTHER\_CROPS + \beta_3 PRUNE + \beta_4 RUST + \beta_5 BORER + \beta_6 ARABICA + \beta_7 REGION + \beta_8 REPLANT + \beta_9 LABOUR + \beta_{10} FARM\_SCALE + \beta_{11} PPAP + \varepsilon$$

Where COFFEEprod, TREE_AGE, OTHER_CROPS, PRUNE, RUST, BORER, ARABICA, REGION, REPLANT, LABOUR, FARM_SCALE, PPAP and ε are coefficients associated with the average quantity of coffee produced in number of 60kg bags, tree age in years, other crops cultivated on coffee plot, number of times of pruning coffee trees per year, presence of coffee leaf rust disease on coffee plot, presence of coffee berry borer on the coffee plot, coffee variety cultivated, region of PNG where coffee plot is located, replanting of coffee, type of labour used, scale of coffee production, whether a coffee farm benefits from PPAP and error term which is Independently Identically Distributed (IID).

The functional form for the FARMER ATTRIBUTES model is the following (2):

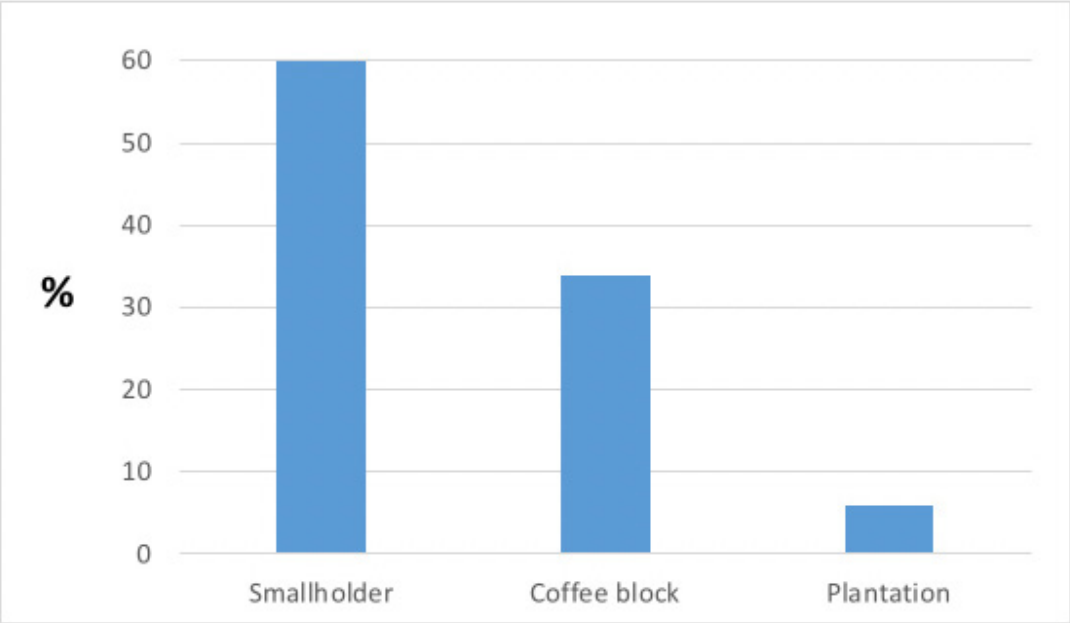
$$Log(COFFEE_{prod}) = \beta_0 + \beta_1 INCOME + \beta_2 GENDER + \beta_3 EDU + \beta_4 AWARE + \beta_5 HHOLD + \beta_6 MARITAL + \beta_7 Log(EXPERIENCE) + \beta_8 COOP + \beta_9 TRAIN + \varepsilon$$

Where INCOME, GENDER, EDU, AWARE, HHOLD, MARITAL, EXPERIENCE, COOP and TRAIN are coefficients associated with household disposable annual income in PNG Kina, gender of the interviewee, awareness of the economic productive age of coffee tree, interviewee's household size, marital status, number of years the interviewee has been growing coffee, membership of coffee cooperative and participation in training on coffee production.

Findings from the study

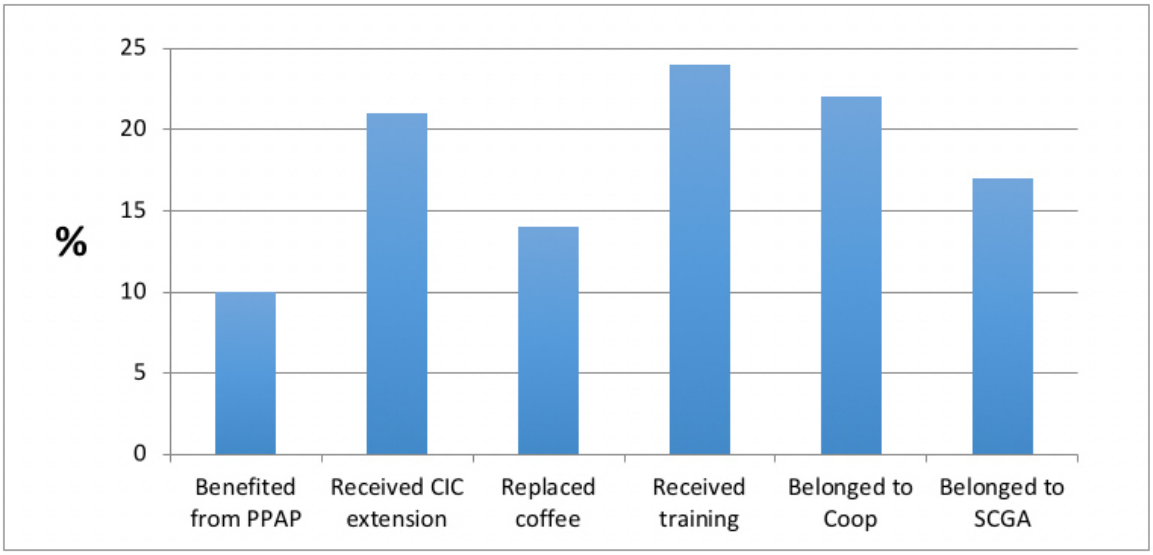
Of the 510 coffee growers that were interviewed, 22.2 percent had their coffee farms in Morobe Province, 38.4 percent had farms in Eastern Highlands Province and 39.4 percent in Western Highlands Province. Most of the interviewees were smallholders, (60%), followed by coffee block (34%) and only a few (6%) owned coffee plantations (Figure 3).

Figure 3. Categories of coffee growers in %



Of all the interviewees, only a few (10%) benefited from PPAP and only a few (21%) received extension services from CIC annually (Figure 4). Only a few of the interviewees replaced coffee trees in their coffee plots with other crops (14%).

Figure 4. Description of some variables in %



Of all the interviewees, only 24 percent received training in coffee production in the past three years starting from 2018 (Figure 4). Only 22 percent belonged to a cooperative society and 17 percent of the smallholder coffee growers belonged to Smallholder Coffee Growers Association (SCGA).

Comparison between some variables in relation to study areas

Of the three provinces that were studied, Eastern Highlands Province (EHP) had the oldest coffee trees and Morobe Province (MP) had the youngest trees (Table 1). Most coffee growers in EHP cultivate other crops on their coffee field and MP had the highest number of pruning each year. Growers in MP were the most affected by leaf rust disease and coffee berry borer (Table 1).

Table 1. Description of some variables in relation to study areas

Description	Percent/mean		
	EHP	MP	WHP
Estimate of age of coffee trees on the coffee field in years	(23.75)	(13.57)	(22.57)
Other crops are grown with coffee on the same plot	78	54	73
Number of times pruning is conducted each year	(1.44)	(2.17)	(1.55)
Problem of leaf rust disease in the coffee field	77	81	56
Problem of coffee berry borer in the coffee field	56	79	51
Arabica coffee is grown on coffee field	71	54	36
Robusta coffee type is grown on coffee field	7	21	7
Coffee growers who replanted some coffee trees in last 10 years	83	99	38
Coffee growers who converted coffee fields to that of another crop	7	9	26
Coffee growers who received extension services from CIC each year	15	45	14
Coffee growers who benefited from PPAP	9	18	6
Coffee growers who received training in the last 3 years	26	35	15
Coffee growers who are members of a cooperative society	17	53	8
Coffee growers who are member of SCGA	15	29	12
Coffee growers who knows about productive age of coffee tree	84	69	69
Number of years coffee grower has engaged in growing coffee	(27.65)	(14.28)	(25.79)

EHP is Eastern Highlands Province, MP is Morobe Province, WHP is Western Highlands Province; PPAP is Production Partnership in Agriculture Project; CIC is Coffee Industry Corporation; SCGA is Smallholders Coffee Growers Association and mean is in parenthesis.

In terms of the replanting of coffee, interviewees in MP were the most successful in replanting. Those in WHP were less successful in the last 10 years (Table 1). Of the three provinces, WHP was associated with the highest conversion of coffee field into that of another type of crops and EHP had the lowest conversion rate. In terms of receipt of extension services from CIC, interviewees from MP had the highest access to the services and WHP had the lowest. Interviewees from MP also had the highest access to PPAP services and WHP had the lowest. MP had the highest members of cooperative societies and membership of SCGA and WHP had the lowest membership. In terms of information about the productive age of a coffee tree, interviewees from EHP were more informed compared to those from MP and WHP. Interviewees from EHP had the highest number of years experience in growing coffee and those from MP had the lowest experience (Table 1).

Variables used in inferential statistical analysis

In terms of data collected from all the three provinces, the results revealed that on average, approximately 42 of 60kg bags of coffee was harvested each year from 2018 to 2020 (Table 2). The average age of trees in the study areas was over 20 years and most of the interviewees grow others crops with coffee on the same plot. The interviewees pruned coffee trees less than two times each year. The problem of leaf rust is more wide-spread in the study areas than coffee berry borer.

Arabica coffee is grown more in the study areas and coffee growers have vast years of experience in growing coffee

(Table 2). More than 50 percent of the interviewees have engaged in planting new coffee trees in the past 10 years and family labour is often used more in farm operations. Only a few of the interviewees belonged to a cooperative society. On average, interviewees had more than 19,000 PNG Kina as annual household income, only a few women engaged in coffee production and the interviewee had a household size of six persons and most were married. Less than 40 percent of the interviewees had a high school education and more than 75 percent had knowledge about the economic productive age of coffee trees.

Table 2. Description and descriptive statistics of variables used in our inferential analysis

Variable	Description		Mean/%	SD
$COFFEE_{prod}$	Quantity of coffee produced from 2018 to 2020 in 60kg bag		(42.11)	510.86
TREE_AGE	Age of coffee trees on the coffee field in years		(20.98)	9.83
OTHER_CROPS	Other crops are grown with coffee on the same plot:	Yes = 1	71	0.45
		No = 0		
PRUNE	Number of times coffee trees was pruned per year		(1.63)	1.51
RUST	Coffee plots affected by leaf rust disease:	Yes = 1	70	0.46
		No = 0		
BORER	Coffee plot affected by coffee berry borer:	Yes = 1	59	0.49
		No = 0		
ARABICA	Coffee variety grown on the coffee plot:	Arabica = 1	55	0.50
		Other coffee types = 0		
REGION	Location of coffee plot:	Highlands region = 1	79	0.41
		Momase region = 0		
REPLANT	Coffee trees were replanted in the last 10 years:	Yes = 1	69	0.46
		No = 0		
LABOUR	Type of labour often used for operations:	Family labour = 1	71	0.46
		Others = 0		
FARM_SCALE	Scale of coffee production linked to farm size:	Smallholder = 0	60	0.61
		Coffee block = 1	34	
		Plantation = 2	6	
PPAP	Farm benefit from Production Partnership in Agriculture Project:	Yes = 1	10	0.30
		No = 0		
INCOME	Household annual disposable income in Papua New Guinea Kina		(19,513)	78,553
GENDER	The gender of the interviewee:	Female = 1	19	0.39
		Male = 0		
EDU	The highest educational level attained by the interviewee:	High school: 1	38	0.49
		Others: 0		
AWARENESS	Interviewee knows about productive age of coffee tree:	Yes = 1	76	0.43
		No = 0		
HHOLD	The interviewee's household size in number of persons		6.31)	3.93

MARITAL	The interviewee's marital status:	Married = 1 Others = 0	77	0.42
EXPEREINCE	Number of years that the interviewee has growing coffee		(24.09)	15.78
COOP	Interviewee is a member of a cooperative society:	Yes = 1 No = 0	22	0.41
TRAIN	Interviewee received training on coffee production in the last 3 years:	Yes = 1 No = 0	24	0.45

Mean is in parenthesis; USD 1 = PGK 3.3 when the study was conducted in 2021

In order to examine factors influencing the quantity of coffee produced, two Ordinary Least Squares (OLS) Models (FARM ATTRIBUTES AND FARMER ATTRIBUTES) were estimated (Tables 3). The FARM ATTRIBUTES model focused on the coffee plot characteristics and the FARMER ATTRIBUTES model focused on the coffee grower's (interviewee) characteristics that influence quantity of coffee produced. The coefficient of determination (R2) for the models ranged from 19.7 percent to 28.2 percent, which indicate the variability predicted by the regressors. The F value for the two OLS models ranged from 6.1 to 9.4 and was statistically significant at the 0.1 percent significance levels, which indicate the overall significance of the models.

Findings from the FARM ATTRIBUTES model show that the coefficients associated with coffee tree age, number of times of pruning of a coffee tree each year, presence of Arabica coffee variety in the coffee plot, coffee planted in the Highlands region of PNG, scale of coffee production and the coffee plot that benefits from PPAP were positive and statistically significant. It imply that an increase in the coefficient associated with tree age, an increase of number of pruning of coffee tree, presence of Arabica in the coffee plot, coffee plot located in the Highlands region, an increase in the scale of coffee production and the implementation of PPAP result in an increase in the quantity of coffee produced.

Coefficients associated with the growing of coffee and other crops on the same plot and the type of labour used for farm operations were negative and statistically significant. It means that the coefficient associated with planting of other crops on coffee plot and the use of family labour result in a decrease in the quantity of coffee produced. The coefficients associated with the presence of coffee leaf rust, coffee berry borer and replanting of coffee trees were not statistically significant, which imply that these coefficients do not matter when it comes to the quantity of coffee produced.

For the FARMER ATTRIBUTES model, the coefficients associated with household income, education, awareness of the economic productive age of coffee tree, number of years of experience in coffee production, membership of cooperative society and participation in the training in coffee production were positive and statistically significant. This means that an increase in the coefficient associated with income, attainment of a high school education, having information about the economic productive age of coffee tree, an increase in the number of years of being engaged in growing coffee, being a member of a cooperative and participation in training on coffee production, are associated with an increase in the quantity of coffee produced.

Coefficients associated with gender, household size and marital status were not statistically significant. This implies that gender, household size and marital status of a coffee grower does not matter in the quantity of coffee that the grower produced.

Table 3. Ordinary Least Squares regression model results of factors influencing quantity of coffee produced

Variable	Dependent variable is the annual quantity of coffee harvested in 60kg bags					
	FARM ATTRIBUTES			FARMER ATTRIBUTES		
	Coeff.	SE	t-value	Coeff.	SE	t-value
Constant	0.81	0.36	2.28**	0.12	0.34	0.37
Log(TREE_AGE)	0.26	0.09	2.71***			
OTHER_CROPS	-0.25	0.13	-1.95**			
PRUNE	0.09	0.03	2.58***			
RUST	-0.16	0.15	-1.11			
BORER	0.10	0.13	0.77			
ARABICA	0.28	0.13	2.14**			
REGION	0.84	0.14	5.80****			
REPLANT	-0.03	0.15	-0.19			
LABOUR	-0.57	0.13	-4.37****			
FARM_SCALE	0.41	0.13	3.28***			
PPAP	0.29	0.17	1.64*			
INCOME				0.00	0.00	5.21****
GENDER				0.06	0.22	0.25
EDU				0.39	0.16	2.46**
AWARENESS				0.42	0.19	2.10**
HHOLD				0.01	0.03	0.19
MARITAL				0.13	0.18	0.71
Log(EXPEREINCE)				0.44	0.09	4.79****
COOP				0.29	0.16	1.86*
TRAIN				0.42	0.16	2.62***
R^2	0.28					0.19
Adjusted R^2	0.25					0.16
F-value	9.39****					6.09****
No. of observations	275					234

*, **, ***, **** are statistical significance at 10%, 5%, 1% and 0.1%; SE is standard error; and Coeff. is coefficient.

In terms of elasticity, an increase in the coefficient associated with coffee tree age by one unit is associated with an increase in the quantity of coffee produced by 0.26 percent of 60kg bag of coffee. Coefficient associated with the presence of other crops on coffee plot is associated with a decrease in the quantity of coffee produced by 25 percent of 60kg bag of coffee. An increase in the coefficient associated with pruning of coffee tree by one unit is associated with an increase in the quantity of coffee produced by 9 percent of 60kg bag of coffee. Coefficient associated with presence of Arabica is associated with an increase in coffee production by 28 percent of 60kg bag of coffee. The coefficient associated with the region where coffee plot is located is associated with an increase in coffee production by 84 percent of 60kg bag of coffee. The presence of coefficient associated with labour type used in farm operation

is associated with a decrease in coffee production by 57 percent of 60kg bag of coffee. An increase in the coefficient associated with the scale of coffee production results in an increase in coffee production by 41 percent of 60kg bag of coffee. The presence of coefficient associated with PPAP results in an increase in coffee production by 29 percent of 60kg bag of coffee.

An increase in the coefficient associated with income by one unit is associated with an increase in the quantity of coffee produced by 0.0017 percent of 60kg bag of coffee. The presence of coefficient associated with education results in an increase in the quantity of coffee produced by 39 percent of 60kg bag of coffee. The presence of coefficient associated with having information about the economic productive age of coffee tree is associated with an increase in the quantity of coffee produced by 42 percent of 60kg bag of coffee. An increase in the coefficient associated with the number of years of being engaged in growing coffee by one unit results in an increase in the quantity of coffee produced by 0.44 percent of 60kg bag of coffee. The presence of the coefficient associated with membership of a cooperative is associated with an increase in the quantity of coffee produced by 29 percent of 60kg bag of coffee. Coefficient associated with participation in coffee production training is associated with an increase in the quantity of coffee produced by 42 percent of 60kg bag of coffee.

In terms of the most important four coefficients based on ranking in the FARM ATTRIBUTES model are those associated with the region where the coffee plot is located, labour type, scale of coffee production and PPAP. The most important four coefficients in the FARMER ATTRIBUTES model are coefficients associated with having information about the economic productive age of a coffee tree, participation in the training on coffee production, attainment of a high school education and membership of a cooperative. All these coefficients are important in developing a strategy for boosting coffee production.

Challenges and coping strategy in coffee production as perceived by coffee growers

The interviewees reported that they face several challenges associated with coffee production which include the following:

- Coffee leaf rust disease. The disease affect coffee leaves, which in turn reduce the yield of coffee. Of all the interviewees, 71 percent reported that their coffee plots were infected by coffee leaf rust. Though coffee resistant varieties such as Arabica variety that contains Robusta genetic material can be used to resist coffee leaf rust, some of the interviewees reported they often use traditional methods such as using bush fire around the coffee tree or by cutting infected leaves and sometimes prune stems:

"In order to control leaf rust in my coffee farm, I use fire to burn the bush around the diseased coffee to kill the germs in the soil and I remove all the infected leaves".

More than 10 percent of the interviewees reported that they do not have knowledge of how to control coffee leaf rust, so they did nothing to the infected coffee trees:

"Several coffee trees in my farm were infected but as I do not know how to control the disease, I did nothing".

Some of the interiewees reported that they visited CIC office to sought advice on what to do about the coffee leaf rust but could not get help:

"I went to CIC office to seek help, but I later helped myself when I could not get help from CIC".

- Coffee berry borer. This is the key pest affecting coffee production as reported by the interviewees. Of all the interviewees, 59 percent reported that their farm and harvested coffee beans were infested by berry borer and it has continued to reduce the quality of their coffee. In terms of managing the berry borer, they have either cut down the infested trees or make fire around the infested coffee tree. Some sell their cherries immediately after drying and others have stopped coffee farming because they cannot cope. Almost 16 percent of the interviewees reported that they do not have knowledge on how to manage coffee berry borer, so they did nothing to the infested coffee trees:

"In order to manage the coffee berry borer, I often cut down infested coffee trees and bury the trees outside the coffee plot".

"I make fire around the infested coffee trees to kill the berry borer".

"I reported the problem to the Department of Agriculture and Livestock, I was given medicine but it did not solve the problem".

"I am still waiting for advice from CIC officials, I lack knowledge on how to manage the berry borer".

- Poor access to extension services. Most of the interviewees (78.8%) reported that extension officers rarely visit them to provide them information on modern coffee production techniques. In fact, 67 percent of the interviewees rated extension services provided by CIC to be poor. They reported that for extension services to improve, CIC officers must visit growers and work with them on management of coffee. CIC should also provide more training to coffee growers and that they must do their jobs properly.

"CIC extension officers are not doing their job, they must go out of their offices to visit coffee growers and provide information on how to manage their coffee plots".

"Smallholders must receive training from CIC extension officers, the officers should not go to only coffee plantations".

"Extension officers should be directly involved in field training of coffee growers".

- Poor access to market. The challenges that interviewees face in relation to access to market includes poor transport facilities, especially poor road conditions which restrict them from accessing nearby market. The poor road conditions result in an increase in transport fee which reduces profit made in coffee business. Some of the interviewees complained that middlemen made coffee growers to be price takers and that they have continued to lower the price of coffee, which discourages growers. They would love to sell their coffee directly to coffee exporters instead of middlemen, but it is difficult to find other group of buyers.

"Poor road conditions make it difficult to access market and the low price that middlemen buy coffee from us make coffee business unattractive".

"The corruption that we have been witnessing among some of the cooperatives leaders discourages me from selling my coffee via cooperatives".

"Some middlemen cheat us by telling lies about coffee weight and at the same time buy our coffee at very low prices".

- Interviewees reported that they face challenges in relation to the processing of coffee. The key problem associated with processing include the high cost of labour and shortages of labour for harvesting coffee. Poor access to water for processing coffee and poor road condition, which restricts the transportion of cherries to the processing plant. Inadquate access to electric power for operating coffee processing machine.

"We now find it difficult to get people who are willing to harvest coffee beans in the field, which has made labour price to go up. Poor access to water for processing coffee is another key challenge we face".

"Poor access to electric power for operating coffee processing machine has continued to be a challenge to us. We also find it difficult moving our coffee to the processing plant because of the poor road conditions in rural areas".

Opportunities for coffee production in PNG

Several opportunities for coffee production in PNG exist and these are the following:

- Suitable environmental and climatic conditions for growing coffee. PNG has some areas located in high altitudes where the environmental and climatic conditions are suitable for Arabica. The country also has some areas in low altitudes where the environmental conditions can support the growth of Robusta coffee.
- According to a study by Afolami and Ezebilo (2021), an increase in the coffee harvest area in PNG is associated with an increase in coffee output by 119 percent. The output is higher than each of the top five coffee-producing countries except Vietnam. This indicates that PNG can be one of top coffee-producing countries to the world.
- PNG has several abandoned coffee plantations that can be revitalised to increase the total coffee production in the country.

- PNG has the CIC, which is a specialised agency that focuses primarily on coffee including advice on market prices, providing extension services to coffee growers and advice on coffee production issues.
- Availability of large projects such as PPAP that has the potential to boost coffee production if it implemented in effective and efficient manner.
- PNG has two universities (University of Environment and Natural Resources and University of Technology) that have courses in agriculture for undergraduate and postgraduates studies in agriculture. Thus, skilled labour for coffee production can be provided by the two universities.

Discussion

The findings revealed that PNG has several opportunities for coffee production. However, coffee production in the country is restricted by challenges such as coffee berry borer (CBB), coffee leaf rust (CLR), inadequate access to extension services, and inadequate access to marketing and processing facilities. Coffee production in PNG can be improved by addressing the challenges that restrict the production of coffee. This has the potential to sustain or increase income for coffee growers' households and government revenue. Our findings on pests and diseases are in line with UCDA (2012) and Jima et al. (2017), who found that CBB infestation results in poor quality coffee and CLR infection reduces coffee yield. This results in financial losses to the coffee growers, which in turn result in loss of government revenue. CBB is the main insect pest of coffee which often results in losses of more than US$500 million in coffee-producing countries annually (Infante, 2018). The control of CBB is often difficult because it is protected inside the coffee berry and the availability of coffee berry in the field provide it a conducive environment to survive from one generation to the next. CBB can be controlled using chemicals such as synthetic insecticides. Cultural practices such as the removal of infested berries and by harvesting ripe, over ripe and rasin (dried) berries regularly during harvesting periods with the frequency of two to three weeks intervals (Aristizabal et al., 2016). The cultural practices have been used in Columbia successfully. For the case of CLR, it is a fungal disease that affect the leaves of coffee, but the severity of the disease is lesser at altitude of above 1200 metre (Zambolim, 2016). In Brazil, the losses caused by CLR ranges from 30 to 50 percent. In this study, 56 to 81 of the coffee growers were affected by the disease. CLR can be managed by using resistant coffee varieties and chemicals such as systematic fungicides which include copper and triazoles (Zambolim, 2016).

Extension services is important in providing credible information to coffee growers on modern techniques of coffee production and on how to to address several challenges associated with coffee such as pest and diseases. However, it was found that there is weak extension services in areas studied and most of the coffee growers find it difficult to accessing the services. Our finding is in line with that of several authors such as Tolera and Gabermedia (2015) who found in an Ethiopian study of opportunities and constraints of coffee production that weak extension services constrain coffee production. In a Nigerian study of factors constraining coffee production, Ayoola et al. (2012) found that inefficient extension services restrict coffee production. In this study, only 21 percent of the interviewees reported that they receive extensions services annually. This may contribute to the difficulty that coffee growers, especially smallholders are facing in coffee production in PNG because of inadequate information on how to address problems such as how to manage CBB and CLR. In order to address the inadequacies of the extension services provided by CIC, there is a need for government, through its agencies such as the Department of Agriculture and Livestock and the Department of National Planning and Monitoring, to conduct an extensive evaluation of the activities of CIC in relation to providing extension services to coffee growers. The evaluation will provide the agencies with the information concerning the reason that most coffee growers have been restricted from accessing extension services and how to address the problem.

Access to coffee market provides coffee growers with motivation to produce coffee and vice-versa. However, in this study, poor access to market restricts coffee production potential of the growers. Our result conform with the finding of several authors. For instance, in a Kenyan study of challenges affecting revitalisation of coffee, Theuri (2012) found that inadequate access to coffee market restrict revitalisation of coffee production. Folnovic (2020) found that coffee production is determined by market prices. In PNG, some coffee growers have their farms in remote areas which makes it difficult to transport berry to the market because of poor road conditions and in some cases, the high transport cost discourage growers from taking their coffee to the market. Middlemen often use the opportunity of the predicament faced by coffee growers, especially smallholders, to pay low prices for coffee at the expense of the growers. As the growers does not have alternatives, they are compelled to sell their coffee at low prices because they are made to be price takers by the middlemen. Coffee growers can be assisted to get a fair prices by encouraging them to establish cooperatives and information on current price of coffee passed to them by CIC officials frequently. Government should consider investing more on rural feeder roads so that more farmers can have access to markets.

Coffee processing method and the timing of processing often determine the quality of coffee and consequently the price of coffee. However, access to coffee processing facility is one of the challenges faced by coffee growers in the study area. Our finding is in line with that of Deribe (2019) who found in an Ethiopian study of factors influencing coffee quality that processing technique affect coffee quality. As some coffee growers, especially the smallholders, may find it difficult to buy coffee processing machine, they need to move the coffee to the areas where the machines are. The growers may face similar challenges as that of poor access to markets especially in terms of poor road conditions and the remoteness of some coffee fields. In some cases, inavailability of water and electric power also restrict processing of coffee. Smallholder coffee growers should consider establishing a cooperative which can buy coffee processing machine for use by members.

In terms of modeling farm attributes (characteristics) that determine the quantity of coffee produced by a coffee grower, we found that an increase in coffee tree age, an increase in the number of pruning of a coffee tree, the use of Arabica coffee variety, the growing of coffee in the Highlands region of PNG, an increase in the scale of coffee production and the implementation of PPAP in a coffee farm were associated with an increase the quantity of coffee produced.

Regarding coffee tree age, our finding is in line with that of other authors such as Meister (2018) who found that the tree can live up to 100 years; however, the most productive age is between seven to 20 years. According to our results, the average age of coffee trees in our study areas ranges from 14 to 24 years. It is important to note that in our data, we found that 50.6 percent of the coffee trees in the areas did not exceed 20 years of age and the remaining trees (49.4 percent) exceeded the 20 years mark. This indicates that there are many trees in the study areas that have passed their economic productive age, thus there is a need for CIC to create more awareness on the need to replace old coffee trees with new ones. CIC should encourage coffee growers by providing them healthy coffee seedlings at subsidised prices. This can revert the current decline in coffee production been faced by PNG.

Our finding associated with the number of pruning conforms to that of Dufour et al. (2019) who found in an Indonesian study that pruning of coffee trees results in a significant increase in coffee yield compared to the yield from unpruned trees. In fact, pruning contributes in reducing the CBB infestation. Our results show that coffee growers in the study areas conduct pruning one to two times each year. The growers should be reminded about the benefits they can get from pruning their coffee trees such as increase in yield and the reduction in CBB infestation which has been one of the main problems that they face.

Bekele and Guadie (2020) found in an Ethiopian study that types of coffee determines the quantity of coffee produced. It is well known that Arabica variety produce more coffee than other coffee varieties (Winston et al., 2005). Our findings support that of these authors. However, it is important to note that Arabica can only do well in high altitude (from 1200 meter above sea level). Though Arabica can increase coffee production, we need to be mindful about the geography of the areas where coffee is grown to achieve the potential yield. This imply that the environmental conditions of an areas will determine the varieties of coffee to be grown.

In terms of region of PNG, the Highlands region has been known to dominate coffee production, and growers in the region mainly grow Arabica which is suited to the environmental conditions there (Afolami and Ezebilo, 2021). In this study we found that the growing of coffee in the Highlands region result in an increase in coffee production. The finding may be because of the presence of conducive environmental conditions there for coffee production. However, it is important to note that Arabica do well in the Highlands region compared to Robusta. Thus, investment in coffee production in the region should focus on the growing of Arabica.

An increase in the scale of coffee production often results in a decrease in the per unit cost of each quantity of coffee produced, that is, economies of scale (Gravelle and Rees, 2004). Our findings revealed that an increase in the scale of coffee production result in an increase in the quantity of coffee produced. This means that coffee production in PNG can benefit from economies of scale. However, the economies of scale can be achieved by increasing the scale of production by revitalising the abandoned plantations and providing land for expanding coffee plots for growers who wish to do so. Our finding is in line with that of Balgah (2019), and Bekele and Guadie (2020) who found that coffee production is determined by the land area under cultivation.

The implementation of an agriculture improvement initiatives has the potential to encourage coffee growers to put more effort in producing coffee especially when it has to do with improving access to markets. The PPAP has been used to improve the value chains in coffee-producing areas and rehabilitate facilities associated with accessing markets and providing extension services. We found that the implementation of PPAP result in an increase in the quantity of coffee produced. According to our results, only 10 percent of the coffee growers that were interviewed benefitted from PPAP. If the intention is to improve the coffee production in PNG, all coffee growers should benefit from PPAP. This is because the growers that have not benefited from PPAP may think that the government is not interested in assisting them to improve coffee production. In fact, some of the interviewees believed that the PPAP is discriminatory.

The growing of other crops on coffee plot and the use of family labour for farm operations were found to decrease the quantity of coffee produced. Coffee growers often practice intercropping of coffee with other crops. However, our findings suggest that the growers should practice intercropping with caution. This is because some of the crops used for intercropping may not be compatible with coffee and others may compete for resources such as labour, fertiliser and chemicals used for disease and pest control, which may result in the neglect of coffee. For instance, in the study areas, some coffee growers have replaced coffee trees with other crops with shorter rotation periods and others have focused more on the growing of vegetables and does not have time to conduct farm operations such as pruning and harvesting coffee in a timely manner. The result indicates that if coffee growers want to increase coffee production, they should consider focusing more on their coffee than other crops grown on the coffee plot.

Several authors such as Trevisan (2018) and Folnovic (2020) have found that type of labour influence the quantity of coffee produced. Though most coffee growers in our study areas especially smallholders use family labour in their farm operations, we found that it results in a decrease in the quantity of coffee produced. A possible reason for the result is that family labour is not often disciplined by market forces of demand and supply. As people who supply family labour are not paid for the work done, they may use a lesser effort and lesser active time in conducting farm operations compared to hired labour that are paid and supervised. Thus, the use of family labour in coffee production is not efficient. Our finding suggest that if a coffee grower wish to practice commercial coffee production or to maximise his or her potential, the grower should consider using hired labour in farm operations. Family labour may not be reliable and may use much time in doing things that does not relate to farm operations without been reprimanded by farm owner who happens to be his or her relative.

In terms of farmer's characteristics that determine the quantity of coffee produced, we found that an increase in income, attainment of at least a high school education, awareness of the economic productive age of a coffee tree, an increase in the number of years of being involved in coffee production, membership of a cooperative society and participation in coffee production training increases the quantity of coffee produced. For income, our finding is in line with that of authors such as Bekele and Guadie (2020), Ayoola et al. (2012) and Folnovic (2020) who found that income, capital and finance determine coffee production. In PNG, accessing agricultural credits is often a difficult task for farmers including coffee growers, especially smallholders. Thus, growers who have much money can buy all farm inputs they need and this in turn increases the quantity of coffee produced. The government can do more by making credit facilities more accessible for farmers who need the facilities. Our finding indicate that if coffee growers are given the opportunity to access loans, coffee production will increase in the country.

Education and awareness provide coffee growers with the opportunity to access information on how to improve coffee production by using modern farm practices and new innovations. Our findings show that access to basic education and the awareness of the life cycle of coffee plant increases coffee production. Our findings are in line with that of Nchare (2007), and Tolera and Gabermedia (2015) who found in their studies that educational level and the degree of access to extension services influence coffee production. The government can consider providing adult education classes for coffee growers who did not have the opportunity to attend formal education. This will assist the growers in accessing information they need in improving coffee production.

Experience provides an individual more opportunities to learn more about a subject of interest. Our finding on the number of years that the interviewee has engaged in coffee production is in line with the premise. It suggests that coffee growers who have been involved in growing coffee for many years will have more knowledge and experience

in handling most of the challenges associated with coffee than those who have a few years of experience. This highlights the need for CIC extension officers and researchers to work closely with experienced coffee growers because some of them may have more information on potential solutions to some challenges being faced in coffee production.

In terms of membership of a cooperative, several authors have shown that it contributes in increasing coffee production. For instance, Singere et al. (2019) found that cooperatives can improve coffee production and quality. Trebbin (2014) found that cooperatives reduce transaction costs and increases coffee production. In our study, we found that membership of a cooperative results in an increase in the quantity of coffee produced. A reason may be that a cooperative assists its members to address several challenges they face. Cooperative is also a forum where members can access information, advice, encouragement and networking which can assist coffee growers in improving the production of their coffee. Though there are several coffee cooperatives in PNG, some have fold-up and others are struggling to remain afloat (Altman et al., 2020). Government, through its agencies responsible for cooperatives, should assist the cooperatives with training on how to promote sustainability in coffee production. Cooperatives have the potential to transform the coffee industry by revatilising coffee plantations. If a coffee cooperative is managed properly, it can operate a coffee plantation by allocating portions a plantation to its members and manage activities of the members.

Training of coffee growers is important in providing them with information on modern ways of coffee production and to understand the challenges they are facing. It is also a forum where growers can exchange ideas on new innovations and techniques in coffee production. We found that participation in training on coffee production results in an increase in the quantity of coffee produced. A possible reason may be that growers who participated in coffee production training accessed information on how to address challenges that limit production, which must have assisted them to increase production. This highlight the need for providing training sessions for coffee growers at least annually by CIC in collaboration with the Department of Agriculture and Livestock. It can provide the growers with the opportunity to learn new things and to discuss the challenges they are facing.

In terms of the most important determinants of the quantity of coffee produced that coffee industry improvement strategy should focus on include the following:

- Geography of the areas where coffee are cultivated. Coffee is doing well in the Highlands region, especially Arabica, which is a high quality variety that attracts high price in the market. The government should consider addressing the challenges, especially poor access to market that growers in that region face.
- Access to labour is important in the production of coffee. Though PNG has a huge youth population, most of them want to move to urban areas where infrastructure such as piped water, electric power and good networks are. This results in labour shortages in rural areas where coffee is often produced. Government should consider providing more infrastructure in rural areas.
- Coffee production in PNG can increase by increasing the scale of production and benefiting from economies of scale. Government should consider revitalising all the plantations that are currently not in operation. Some smallholder coffee growers may wish to expand their coffee enterprises but access to large land is an issue. It is important to address the issue by implementing all recommendations made in the 2019 National Land Summit.
- PPAP is an important project that has the potential to motivate coffee growers to increase production. However, only a few of the growers are benefiting from the project. Government should find a way to make all coffee growers to benefit from PPAP or other projects that can provide similar deliverables.
- Training of coffee growers on coffee production is important in providing them with information on latest innovations and techniques that can be used to boost coffee production. Government should consider funding the training of coffee growers through CIC annually.
- There is a need to consider conducting evaluation of extension services provided by CIC so that the challenges restricting the delivery of quality services can be identified and addressed.

– Basic education will provide coffee growers opportunity to access information they need to improve coffee production. Government should consider providing out of school education (adult education) to farmers including coffee growers who does not have basic education. Apart from giving farmers opportunity to access information related to farming, it will also contribute to increasing the literacy rate of PNG.

In terms of opportunities that PNG has in being one of the top coffee-producing countries in the world, growers should find a way to maximise the use of good environmental conditions by growing coffee varieties that are suitable for each of the regions. CIC should identify areas of weakeness in its operations and address the weaknesses so that coffee growers can use the services provided by CIC to improve coffee production. It is important for CIC to collaborate more with coffee growers in all coffee-producing provinces so that challenges facing coffee production in PNG can be addressed.

PPAP is a project that has the potential to move coffee production in PNG forward to the next level. Thus, all coffee growers should benefit from the project and the project should be implemented in an effective and efficient manner so that the impact created by it can be sustainable. The PNG University of Technology and the University of Environment and Natural Resources have the potential to provide the most needed skilled manpower to revitalise and manage coffee plantations. The government, through its agencies such as Department of Agriculture and Livestock, should consider developing intiatives for training agriculture graduates from the above universities on how to manage coffee plantations. Upon completion of the training, the graduates should be employed in the revitilised plantations. In order for PNG to maximise the opportunities it has in coffee production, CIC, the universities and Department of Agriculture and Livestock should work together and share information aimed at improving coffee production in PNG.

Conclusion

The study reported in this paper aimed to investigate factors that determine the quantity of coffee produced, challenges and opportunities in coffee production in three top coffee-producing provinces of PNG. The findings revealed that the most important factors that determine the quantity of coffee produced include the location of a coffee plot, type of labour used in farm operations, the scale of coffee production and the use of PPAP to improve coffee production. Others include access to information on the economic productive age of a coffee tree, participation in training on coffee production, education and membership of a coffee cooperative. Though PNG has several opportunities to be one of the top coffee-producing countries in the world, several challenges restrict the country from achieving its full potential in coffee production. The challenges include pests and diseases such as coffee berry borer and coffee leaf rust, which lower the quality and quantity of coffee produced respectively. Other challenges include poor extension services, poor access to market and coffee processing facilities.

The opportunities that PNG has in improving the quantity of coffee produced include the availability of environmental and climatic conditions that are conducive for both Arabica and Robusta coffee, availability of coffee plantations that can be revitalised, the presence of a government agency with the sole responsibility of promoting coffee production. Others include availability of two universities that can provide skilled labour to manage coffee plantations and the presence of several coffee cooperatives.

If the intention is to improve coffee production as a way to increase income for coffee growers and increase government revenue from coffee, it is important to grow coffee varieties in the regions they are suitable for, use hired labour in farm operations, produce coffee in large scale and all coffee growers should benefit from PPAP. Improve the extension services provided by CIC to educate growers about the life cycle of the coffee tree, CIC and agencies such as the Department of Agriculture and Livestock should organise training workshop for coffee growers at least once each year and growers should be encouraged to develop or join a coffee cooperative. Challenges that restrict coffee production should be addressed by CIC in collaboration with the Department of Agriculture and Livestock and coffee growers. For instance, there are several cultural practices and chemicals that can be used to control coffee berry borer and coffee leaf rust. CIC extension officers have the responsibility to pass the information to coffee growers and the government should consider subsidising the price of chemicals that can be used for the control of coffee pests and diseases.

In terms of challenges associated with marketing and processing, government should encourage the formation of cooperatives by developing an incentive mechanism that focuses on cooperative management training and providing cooperative coffee processing facilities at a subsidised price. More rural feeder roads should be constructed and existing ones maintained. Information on the current prices of coffee should always be provided by CIC to coffee growers, including smallholders through short message service (sms) through cooperatives and radio. This will provide the growers a reference point that can be used for negotiating price of coffee with buyers. It is important for all the stakeholders in the coffee production chain to work together by sharing information to improve the current situation in the coffee industry.

This Discussion Paper contributes to the strategy on how coffee production can be used to improve the standard of living of coffee growers and increase government revenue from coffee through tax. The findings will assist policy makers, planners, agriculture managers and coffee producers in making informed decisions on how to improve coffee production by considering the allocation of resources aimed at maximising output of coffee, and at the same time address challenges associated with coffee production process.

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