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Malaria and pneumonia effects on rice, vanilla production and rural household income in Madagascar: case of the Sava region

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Abstract

In Madagascar, malaria remains the leading cause of consultation and deaths at hospital at all ages and pneumonia is one of the main causes of the under-five mortality and account for 45 % of children hospitalizations. The number of these cases and deaths has not decreased during the last ten years. This paper aims to determine the effects of malaria and pneumonia cases on rice and vanilla production and income. We used data from a cross-sectional survey conducted in 2016 by the authors on 975 rural households and 3,586 individuals of the SAVA region in the northeast of Madagascar. After checking the presence of endogeneity, ordinary least-square method was used instead of two-stage least squares. Our results showed that malaria has no effect on production, and therefore does not affect income. Pneumonia has an effect on production of rice and vanilla. Moreover, the cost of malaria and pneumonia healthcare burdened by households affect their consumption by reducing expenditure on housing. There are many campaigns for the fight against malaria in Madagascar, but pneumonia prevention measures are very rare. Therefore, pneumonia should be considered in the same way as malaria due to its effects on production and investment to fight against these two diseases must be strengthened in order to decrease the costs for the households.

Keywords: cost of malaria and pneumonia, disease effect, production function, income function, rice crop, vanilla crop

1 Introduction

Diseases affect households' welfare directly by their effect on income and indirectly by the healthcare cost. By reducing physical capacity, they induce a decline in labour productivity, then in production and therefore in income (Grossman, 1972; Audibert, 1986). For a sick child, the reduction in cognitive capacity affects education, therefore the qualification of the future workforce and future income (Schultz, 1961; Thuilliez, 2009).

The prevalence of malaria and pneumonia is still high in Madagascar and may induce a loss of welfare for affected households. As for malaria, Madagascar ranks second among the 10 countries with the highest malaria burden in Africa, and the number of cases exceeded 300,000 in 2017. (WHO Report, 2018). Malaria remains the leading cause of morbidity and mortality in Madagascar (Ministry of Health, 2020). For pneumonia, the incidence rate of 11 per 1000 inhabitants is still higher than the national target of 4 per 1000 inhabitants (Ministry of Health, 2020). Pneumonia is the first cause of consultation and the leading cause of death for children under five. According to the Ministry of Health, 45.4 % of hospitalizations and 5.8 % of hospital mortality for children under five years were related to pneumonia (Ministry of Health, 2012). There are many campaigns for the fight against malaria in Madagascar, but pneumonia prevention measures are very rare (Razakamanana *et al.*, 2020). According to Grossman (1972), diseases affect the economic situation of households, so pneumonia should deserve as much attention as malaria. Therefore, this paper aims to determine the effects of malaria and pneumonia on production and income of households in Madagascar, by studying the case of the SAVA region, northeast Madagascar.

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Concerning effects of malaria, several authors suggested that it does not affect household production or income. Because of the risk of contracting malaria, rural population in endemic areas avoid practicing intensive cultivation (Breman *et al*., 2006). Audibert *et al*. (2009) in their research on the effects of malaria on the production of cocoa and coffee in Ivory Coast, found non-economic effect of malaria. They explained that malaria causes only little or no disability. Generally, fever, nausea and tiredness last on average three days. For Russel (2004) malaria costs are low (from 4.54 % to 7 % of income per month in Nigeria). On the opposite, the effect on production can be significant if malaria occurs during periods of extensive agricultural work (Kioko, 2013). Audibert *et al*. (2003) found significant effects of malaria on cotton production as this crop requires intensive cultivation. Willis & Hamon (2018) found that eliminating malaria in sub-Saharan Africa by 2040 would lead to a reduction in poverty rates among agricultural households by 4 to 26 percentage points. Indirectly, diseases cause loss of time, as more household time may be devoted to caring for the sick. Part of the time intended for producing, studying and performing non-market activities is spent on care (Grossman, 1972; Attanayake *et al*., 2000; Ersado *et al*., 2004; Hailu *et al*., 2017). Beside time lost, malaria induces financial cost for healthcare (Hailu *et al*., 2017). If the cost burdened by households is too high, they may choose as a solution, either to reduce their consumption of non-medical goods, to resort to savings, to sell goods, to use borrowing, or to mortgage their own property. This situation can cause the fall in their savings, or the reduction in their assets, and influences not only the current consumption but also their future consumption (Prescott, 1999).

Studies on pneumonia focused on the cost of this disease and his treatment but not on its effects on agricultural production or income (Du *et al*., 2021). Studying the case of two companies in the United States, Sato *et al*. (2013) showed that the number of wasted day due to pneumonia was three times higher than that due to other sickness. According to Santana *et al*. (2018), absenteeism and deaths due to pneumonia have a significant cost.

The first objective of this paper is to determine the effects of both diseases, malaria and pneumonia, on production and income of households of the SAVA region. We chose to study rice, which is the staple food of the Malagasy people and vanilla, which is the main agricultural export product (Comtrade, 2019). Then, this region is the main producer of vanilla in Madagascar, 28 % of all cultivated areas, and rice constitutes 40 % of all cultivated areas (CREAM, 2016). The second objective is to estimate malaria and pneumonia healthcare cost. The SAVA region was chosen because malaria was the leading cause of morbidity and mortality, and pneumonia was the sixth leading cause of hospital morbidity and the third cause of mortality at all ages (Ministry of Health, 2012).

2 Materials and methods

Our study focused on the rural areas where 80 % of Malagasy people live and where diseases prevalence is highest. In 2016, malaria prevalence was higher in rural areas (5 %) than in urban areas (2 %) (INSTAT, 2017). In addition, cooking with wood, charcoal, or cow dung is the main risk factor for pneumonia in rural area. Thus, pneumonia due to the type of cooking fuel is more common in rural areas than in urban areas (Ministry of Health, 2007).

2.1 Study area

SAVA is a region of the northeast of Madagascar, constituted by four districts: Sambava, Antalaha, Vohémar and Andapa. Sambava, the regional capital, is located at 1,194 km from Antananarivo, the capital of Madagascar. SAVA region has a dense hydrographic network. Its climate is characterised by a dry and cool season from May to November and a warm and humid season beginning in December. The strongest heat is recorded in January and February, while July and August are the coolest months. The annual temperature varies from 18 °C to 31 °C. Of the 1.3 million hectares of arable land 14.8 % was exploited in 2016, including 28 % for vanilla and 11 % for coffee (CREAM, 2016). The remaining area was used for food crops such as maize, cassava, sweet potatoes, beans, vegetables and tropical fruits (CREAM, 2016).

Agricultural techniques used are still rudimentary. The use of agricultural machinery, organic or chemical fertilisers and pesticides is not yet sufficiently developed (CREAM, 2016). Concerning rice crop, soil preparation for sowing is carried out from November to January and consists of irrigating and trampling of the soil. Weeding and harvesting are done manually. It takes place between May and July. Vanilla crop is one of the main sources of income in the region (CREAM, 2016). From September to October, men and women carry out the hand pollination of vanilla. Pods are harvested and scalded between June and September.

2.2 Data collection

In 2016, we conducted a cross-sectional survey in the SAVA region, in the district of Sambava, Andapa and Antalaha. The questionnaires were prepared by reviewing relevant literature. Two types of questionnaires have been administrated, one for the household survey and one for the

individual survey. The survey and study was reviewed and approved by the Ministry of Health of Madagascar (258 MSANP/SG/DGS/DSMER/SPPCM 14 May 2014).

For the household survey, the head of the household or his wife or female headed household in case of single mother was the respondent. This questionnaire included three modules: household characteristics, household farming, household expenditures and consumption. The first module provided information about demographic characteristics, the number of individuals in the household and the characteristics of the dwelling. It allowed to obtain information about household living conditions and to know whether these conditions could explain the transmission and the prevalence of malaria and pneumonia in the region. The second module concerned agricultural activities and provided information on the use of agricultural production (sale, consumption or others) and non-agricultural activities. This module provided information on the overall production, the use of extra-family labour and the total income of the household. The third module provided information on household expenditures structure. It allowed to know how households manage their portfolios in case of illness and check if the disease affected their non-medical goods consumption or not.

Then, for the individual survey, each individual also living in the household, including all children, was interviewed. If the child was under 15, the child's guardian was interviewed. It aimed to provide information on the individual health status. This information provided information on the individual health-seeking behaviour and the cost of the diseases. Specific questions concerned malaria and pneumonia. Malaria was considered when the respondent reported having suffered from a malaria episode and which has been confirmed by a rapid diagnostic test at the health centre or by the Community Health Worker (CHW). Pneumonia was defined as the declaration of an episode of "pneumonia", diagnosed at the health centre or by the CHW. For people who had suffered from malaria and pneumonia the year before the surveys, for patients visiting health centres or CHWs, treatment costs (consultation + medicines) were taken from the consultation booklets or registers. Then, transport costs were asked to the households.

2.3 *Study size and selection of study population*

At the level of each district, first, the communes were randomly selected. The number of communes to be drawn was based on the total population of the communes. The selection was stopped as soon as the number of people in the sampled communes reached 50 % of the total population of the district. In this way 27 communes were selected in total: 11 out of 27 in Sambava, 9 out of 17 in Andapa, and 7 out of 14 in Antalaha. Then, all villages that were more than five kilometres from the nearest health centre of each selected commune were included in the sample. The number of households to be surveyed in each village was determined according to the number of households in the village, so that "n" households were surveyed in each district. The "n"' households were selected randomly. For the sampling, the calculation of "n" was as follows:

$$n = (Z^2 \times P(1 - P))/E^2 \quad (1)$$

$Z = 1.96$ was the statistical value corresponding to a level of confidence of 95 %; E was the margin of error; P represented the average malaria prevalence rate in the region, which was equal to 30 % (Data of the SAVA Regional Health Office, 2015). Subsequently, 325 households per district were surveyed. During the survey, data on the prevalence of pneumonia was not available. Households to be surveyed were randomly selected according to whose head was willing to give consent for the survey. Thus, households that did not give their consent were replaced and were not interviewed. For the individual survey, all children and all adults living in the household were surveyed. In this way a total 3,586 persons were interviewed.

2.4 *Econometric model: effects of malaria and pneumonia on rice and vanilla production and income*

The model used by Ersado (2005) when he studied the relationship between the use of irrigation dam, level of production and health for the case of Ethiopia was applied. This paper was considered because it covers both health and productivity, it considers two products and it is also a low-income country case. The same model as the author was considered, but replaced cereals and vegetables with rice and vanilla.

Since none of the surveyed individuals reported having simultaneously suffered from malaria and pneumonia in the year prior to the survey, comorbidity was not included in the model. Households cultivated food and cash crops. They mainly produced rice as food crop and vanilla as cash crop (CREAM, 2016). Thus, two types of agricultural function were considered, one for the rice and one for the vanilla. Each agricultural production function was as follows:

$$Q = Q(T, L_{ef}, P, E, S, A, H, M, V) \quad (2)$$

With Q: the production of rice or vanilla in kg given the cultivated area.

T: total cultivated area in rice (or vanilla) in m^2.

L_{ef}: use of extra-family labour (binary, 1 if yes and 0 if no). Households engage extra-family labour, especially dur-

ing the period of land preparation, rice harvest and during the period of hand-pollination of vanilla.

P: practice of agricultural activity (binary, 1 principal and 0 if secondary). $P = 1$ if the household works the land for food, cash crops or other purposes as its main activity. On the other hand, $P = 0$ if it is a secondary activity and the household works mainly in the industrial or service sector.

E: level of education, the last class completed by the head of the household. According to Coelli & Fleming (2004), the producer's level of education has a positive impact on the level of production.

A: age of the head of the household. The relationship between A and the level of production can be positive or negative. Some authors said that young people may adopt different and more modern production techniques, while others think that older people are more experienced (Coelli & Fleming, 2004).

S: sex of the head of household. It is a binary variable with $S = 1$, if the head of household is a woman, otherwise $S = 0$. Most studies have shown that the production and income are lower when the head of household is a woman (Coelli & Fleming, 2004).

M: size of the household must be considered when family members help each other in carrying out agricultural activities (Omrane, 2008).

H: health variable. H_1 measured the total confirmed malaria and H_2 measured pneumonia cases occurred in the household one year preceding the survey.

V: cash crop practice for the rice production function and cultivation of food crops for vanilla production. This is a binary variable equal to 1 if yes, 0 if not.

Since farming was still traditional, households did not use other inputs (fertilisers and pesticides).

The income function R had the following form, taking into account the same variables as in equation (2):

$$R = R(T, L_{ef}, P, E, S, A, H_1, H_2, M) \tag{3}$$

Where R: total household income that included cash crop income (coffee, cocoa, clove and vanilla) and food crop income (the part of food crops being sold on local markets: rice, cassava, sweet potatoes, potatoes, corn, peanuts, peas, lentils, chickpeas, carrot, cabbage, tomato, onion, and fruits). Income from the sale of these products was obtained by multiplying the quantity for sale of each product by the price of the product. For the assessment of total income, agricultural income from the sale of agricultural products and average earnings from non-agricultural activities were considered.

For the variables studied, malaria (H_1) and pneumonia (H_2) endogeneity is suspected. These diseases can affect agricultural production and income and the different agricultural activities can expose individuals to these diseases. Indeed, the humidity in the fields is favourable to the development of mosquito larvae (Kinkingninhoun Medagbe *et al.*, 2020). In addition, cold and humidity can cause a respiratory infection. However, the higher the income of households', the better they can protect themselves against diseases.

First, a health production function was developed to identify the determinants of the occurrence of the two diseases. The number of malaria and pneumonia cases can depend mainly on the environment X where households live (e.g. characteristics of the material of the walls and the roof influencing the presence of mosquitos, the type of fuel used for cooking increasing the risk of pneumonia, due to high levels of indoor air pollution (Adaji *et al.*, 2019)), the practice of agricultural activity P, the use of extra-family labour L_{ef}, and the total cultivated area T. With these three last variables, it is possible to determine whether members of the household were exposed to these diseases due to agricultural activities or not. Finally, total income R was also taken into account.

The health production function is expressed as follows and estimated using a covariance analysis:

$$H = H(X, P, L_{ef}, T, R) \tag{4}$$

The specificity of this analysis was that it considered both quantitative and qualitative variables. Dependent variables were the total number of cases of confirmed malaria and pneumonia in the household in the year preceding the survey.

Then, in both production and income functions, instrumental variables for malaria and pneumonia have been used, according to the results of the health production function. The test of Wu-Hausman, was used to check for the endogeneity of the health variable and to determine the most appropriate method for estimating the production and income functions: the ordinary least squares (OLS) method or the two-stages least squares (2SLS) method, taking into account the endogeneity of the explanatory variables.

3 Results

3.1 Descriptive analysis

The average age of the head of household was 42 years (SD: 13) and 23.8 % were female headed households. Questions about educational attainment were related to the last level completed by the respondent. Most heads of household had at least primary education (53.3 %), but 6.7 % had not followed any education. The average size of surveyed

Table 1: *Number of malaria and pneumonia cases recorded in the year preceding the survey.*

	Malaria cases		*Pneumonia cases*		*Total*
Age group	*women*	*men*	*women*	*men*	*population*
Under-five	12 (3.12)	19 (4.95)	6 (1.56)	2 (0.52)	384
5-15 years	36 (3.85)	44 (4.70)	8 (0.86)	4 (0.42)	935
15-65 years	36 (1.66)	80 (3.69)	10 (0.46)	15 (0.69)	2,166
>65 years	1 (0.99)	0 (0)	0 (0)	0 (0)	101
Total	85 (2.37)	143 (3.99)	24 (0.66)	21 (0.58)	3,586 (100)

Note: frequency (% in brackets)

households was four individuals per household (SD: 1.5, median: 4). 41.4 % of the households were mononuclear with the head of household, spouse and children. The remaining 58.6 % lived either with the parents of the head of household, with the grandchildren, or with the brothers and sisters of the head of household. There were on average two rooms per dwelling (median: 2, varies between 1 and 12 pieces). In 9.1 % of cases, the kitchen served also as a bedroom. The majority (65 %) did not have a chimney, so the homestead could be polluted by cooking smoke. Dwellings were constructed in a traditional way. The roof was made of sheet metal for 64 % of the households and of palm leaves or other vegetal products in 29 %. The walls were made either wood or plant for the majority. The dwellings were thus still precarious and the majority of households did not have access to electricity and used kerosene for lightening (64 %). Access to drinking water was very limited as 62 % of the households did not have access to it. According to the definition of WHO & UNICEF (2015), water is drinkable when it comes from: household connections, public standpipes, boreholes, protected dug wells, protected springs and rainwater collection. Moreover, 76 % of households still used wood for fuel, causing domestic pollution. Finally, only 8 % of households had access to improved sanitation. Possession and use of sanitation facilities contribute to the improvement of hygiene conditions of the population. This information is necessary because dwelling characteristics, domestic pollution and hygiene could explain the prevalence of diseases (Appendix A1).

Among the studied households, 903 (92.6 %) practised agricultural activities and the rest are engaged in non-agricultural activities. Non-farm activities, mainly trade sector, occupied 35 % of the households. Almost all households (81 %) cultivated rice, which is the Malagasy staple food and 38.5 % cultivated vanilla, especially for sale. The mean income was about 5,010,870 MGA (median: 1,700,000) or 1,565 USD (median: 531) per year. This is much higher than the average income of Madagascar, which was 1,193 USD (Data of INSTAT, 2010).

Among surveyed households, 54 % who practised agricultural activities used extra-family labour (EFL), Lef, 43 % during the complete crop cycle, 42 % during rice harvest, and 10 % during the period of soil preparation work. Because of the size of households (on average four individuals per household), the use of EFL was essential. Depending on the size of the cultivated land, a household had on average four EFLs. The average cultivated land area was 5,063 m^2. 14.5 % of the head of households reported at least, one case of malaria among their family members and 4.0 % reported at least one case of pneumonia.

In this study, children under 15 years old were the most vulnerable to malaria and pneumonia; In contrast previous studies (e.g. Yoo *et al*., 2013) have shown that people over 65 years old were the most vulnerable to malaria, no pneumonia cases have been detected in this group. There are no significant differences between the sexes in the burden of malaria and pneumonia ($P = 0.21$ and $P = = 0.37$, respectively; Table 1).

Concerning malaria, the high transmission period is betweenNovember and December, during the rainy season. It is the rice field preparation period and punching period of vanilla. Concerning pneumonia, there was a peak in May, August and from November to January. The month of May corresponds to the cold season. In August, it is neither too cold nor too hot and from November to January, it is the rainy season (Ministry of Health, 2012). The fact that the number of cases of pneumonia was high in August can be explained by other determinants than climate. For both malaria and pneumonia, households mainly consulted health facilities (Appendix A2). For malaria, private doctors were consulted most often after health facilities, and for pneumonia it was CHWs. Hospitalisation was required for severe malaria or pneumonia cases.

Table 2: *Relationship between exogenous variables and production of rice, vanilla and income.*

	OLS		
Variables	*Rice*	*Vanilla*	*Total income*
Constant	-5.5*** (0.00)	2.47*** (0.00)	12.55*** (0.00)
Land			
Area (m^2) (log) T	0.00 (0.70)	0.00 (0.93)	0.06** (0.03)
Labour			
Practice of agricultural activity	-1.25 (0.12)	- -	-0.30 (0.80)
Use of extra-familial labour L_{ef}	0.48*** (0.00)	0.36*** (0.00)	0.53*** (0.00)
Human capital			
Size of household M	-0.02 (0.56)	0.02 (0.62)	-0.02 (0.58)
Head of household			
Sex S	-0.48*** (0.00)	-0.44*** (0.00)	-0.55*** (0.00)
Education level E	0.05 (0.10)	-0.01 (0.84)	0.16*** (0.00)
Age A	0.05*** (0.00)	0.03 (0.23)	0.06*** (0.00)
Age^2	-0.00*** (0.00)	-0.00 (0.43)	-0.00*** (0.00)
Health variables			
Malaria	0.04 (0.59)	0.03 (0.81)	-0.01 (0.94)
Pneumonia	-0.28* (0.09)	-0.51** (0.03)	-0.05 (0.82)
R^2	0.10	0.05	0.18
Fisher	9.03*** (0.00)	3.01*** (0.00)	16.53*** (0.00)
Wu-Hausman Endogeneity test	3.82 (0.14)	0.79 (0.67)	0.49 (0.78)
Number of observations	790	376	864

3.2 Econometric results: Economic losses due to malaria and pneumonia

A correlation between the origin of drinking water, fuel type, light source and malaria, as well as between fuel type, roofing material, the fact that the kitchen also served as a bedroom, and pneumonia was demonstrated (Appendix A3). These variables were used in the endogeneity test (Table 2) and it showed that for the rice and vanilla production functions as well as for the income function, malaria and pneumonia variables were not endogenous. The p-value for this test was greater than 0.05. Therefore, the OLS is used. It is a method for estimating coefficients of linear regression equations. This confirmed the results of the health production function, showing that agricultural activity had no effect on the prevalence of malaria or pneumonia.

Among 975 households surveyed, 790 grew rice (81 %) and 376 vanilla (38.5 %). In addition, calculation of income level was only possible for these 864 households. On the one hand, malaria had no impact on rice and vanilla production, or income. The robustness of these results is tested by using the quintiles, the question was, has malaria a higher economic effect for the poor than the less poor or the rich? The results did not change.

Pneumonia, on the other hand, caused a significant negative effect on the production of rice and vanilla but not on income. Indeed, compared to malaria, symptoms of pneumonia are more severe and may induce higher disability. In the calculation of income, sales of agricultural products and average earnings from non-agricultural activities were considered. For 95.4 % of households who grew rice, it was mainly for self-consumption, while vanilla was for sale (100 %) and generated income. It was noted that 40 % of people over 15 years old with pneumonia carried out non-agricultural activities. Therefore, the existence of an effect on production and not on income can be explained by the compensation between agricultural and non-farm income. Our results showed that the production of rice, vanilla and income depended mainly on the use of extra-family labour, sex of the head of household for vanilla production function, age of the head of household for rice production function as well as on the cultivation of cash crops and food crops for the income function. Indeed, the use of extra-family labour could increase the production and the income. Vanilla production and income were lower when the head of the household was a woman than in the opposite case because of the lack of labour. The older the household head, the higher the production and income, which might be explained by his or her experience. Finally, the practice of cash crop and food crop and the total land area explained the increase in income.

3.3 Costs of malaria and pneumonia

Respondents with malaria or pneumonia consulted public health centres, private health facilities or CHWs. Direct costs included travel, consultation, treatment, hospitalisation, and food expenditures during hospitalisation. The direct costs of malaria accounted for an average of 5.9 % of households' monthly income, regardless of the type of care provided (table 3). Concerning pneumonia, the financial costs were between 3.7 and 5 % of the monthly income of the households. Table 3 shows the costs of these diseases by district.

Table 3: *Direct costs of malaria and pneumonia by district (in USD).*

	Malaria			*Pneumonia*		
	Sambava (N=46)	*Andapa* (N=72)	*Antalaha* (N=79)	*Sambava* (N=16)	*Andapa* (N=16)	*Antalaha* (N=9)
Transport costs	0.67	1.63	1.36	0.59	0.15	0.17
Consultation and treatment fees*	5.70	9.00	8.38	7.70	6.52	6.08
Total costs	6.37	10.64	9.75	8.29	6.68	6.25
Household income per month	165	179	159	165	179	159
Proportion to monthly income (%)	3.8	5.9	6.1	5.0	3.7	3.9

* Costs of possible hospitalisation are not included.

In Andapa and Sambava, the majority of respondents with malaria consulted mainly health centres (28.3 % in Sambava and 41. 7 % in Andapa) or private doctors (39.1 % in Sambava and 20.8 % in Andapa) (Appendix A4). Concerning pneumonia, the cost was lowest in Antalaha where 33.3 %of the households used CHWs. It was the highest in Sambava where the households used mainly health centres or private doctors and dispensary (Appendix A4). Cost of hospitalisation was not yet considered in this Table 3. In the case of hospitalisation, the average cost per episode of malaria was 50.3 USD, or 30 % of monthly household income and 42.8 USD per episode of pneumonia, or 25.6 % of monthly household income. According to the World Bank and Rashidian *et al* (2018) health expenditure is catastrophic if it exceeds a threshold of 20 % of total income. In our case, health expenditure is below these thresholds except in case of hospitalisation (26 cases for malaria and 7 for pneumonia).

Among interviewees, 49 % were willing to pay for care, among them, 11 household heads said that they can pay more than 1,000,000 MGA, or 312.5 USD per year to invest in their health, and the remainder was willing to pay on average 28,600 MGA, or 8.9 USD per year. Half (50.2 %) of the interviewees had no opinion.

4 Discussion

A survey of 975 households and 3,586 individuals was conducted in the SAVA region in Northeast of Madagascar in 2016 in order to determine the economic effects of malaria and pneumonia and the costs of these diseases. Agricultural production functions and income functions were developed.

The results showed that malaria did not affect either production (whether rice or vanilla) nor income. It is in line with previous malaria studies (Russel, 2004; Breman *et al*., 2006; Audibert *et al*., 2009). We can explain this result by the fact that adults affected by malaria were able to continue work to ensure agricultural activities. The mean duration of an episode was six days, and the annual number of episodes of malaria was one per household. In the SAVA region, children under 15 years old were the most vulnerable to malaria. However, the fact that a child falls ill did not necessarily lead to a suspension of household income-generating activities. Another reason was since it concerned household production, the families knew from their experience how to change the division of labour in order to entrust a sick person with less arduous tasks , since the duration of malaria was generally short. Pneumonia, whose symptoms were more severe than those of malaria, negatively affected the production of rice and vanilla. However, the impact on income was not significant, as there is a trade-off between agricultural and non-agricultural income. According to Senadza (2010) and Danso-Abbeam *et al*. (2020), the practice of non-agricultural activities such as trading, salaried employment, self-employment, and other non-farm vocations or enterprises allows compensating for decreases in agricultural production.

Malaria and pneumonia, however, generated financial costs. Malaria cost is close to that found by Russel (2004) who reported that for households in Nigeria, the direct costs of malaria were between 2.6-4.1 % and 4.5-7 % of monthly income (Russel, 2004). Although the health costs were not catastrophic in simple cases, they were catastrophic in cases of aggravation, causing hospitalisation. Therefore, it is always necessary to prevent these diseases or to consult health centres in time. When expenses were too high, this situation caused some households to take out a loan or to sell their assets since they could not modify their non-medical expenditures.

Although Malaria and pneumonia did not affect household income. The diseases generated costs that affected household consumption. Among households with one member affected by malaria or pneumonia, 24 % had to borrow (interest rate information was not available), 5 % had to sell some of their assets. No household had reduced his food and clothing expenditures. Almost, 78 % of surveyed households reported having unmet needs. For 49 %, it concerned housing, which was the most affected need in Sambava, Andapa and Antalaha due to disease costs. Consumptions of food and clothing were not affected, since these were already the minimum for households' members' survival. When expenditures could no longer be changed, households were forced to borrow or to transfer their assets.

Therefore, pneumonia should be considered on the same level as malaria because of his financial burden. Thus campaigns to fight this disease should also be strengthened. According to the International Vaccine Access Centre (2021), pneumonia especially affects people living in the poorest households and in the poorest countries in the world. Indeed, 99 % of child deaths from pneumonia occur in developing countries (WHO, 2020). People with weakened immune systems have a significantly increased risk of pneumonia. The productivity of ill persons is low, exacerbating their poverty and thereby causing a vicious circle leading to intergenerational transmission of poverty.

Concerning rice and vanilla, the production depended mainly on the use of extra-family labour (EFL), sex, and age of the head of household. The absence of one member of the household due to illness did not necessarily lead heads of household to hire an additional EFL, as the duration of the illness was in general short. However, if the illness was prolonged, neighbouring households would sometimes help each other with farm work. Concerning sex, women and men participated in farm activities, but differences in time allocation were observed. According to Kinkingninhoun Medagbe *et al*. (2020), men spent more time in the fields, and domestic duties such as childcare, nursing, and cooking were usually in the hands of women. In this study, the woman became the head of the household when the man was absent or when she was not living with her partner. Thus, she had to take care of the domestic tasks as well as the work in the fields. This explains the lower production and income when the head of the household was a woman. Finally, age affected production through the experiences gained by farmers.

This study strengthens the literature, particularly that on the effects of pneumonia on the production capacities of a rural household. However, this study presents some limitations, we did not ask for the episodes of malaria or pneumonia of extra-familial workforce. In addition, we based our study on declared and confirmed cases, which only partially reflected malaria morbidity and did not reflect the possible state of tiredness caused by this disease. Therefore, it might be better to carry out a biological study.

Supplement

The supplement related to this article is available online on the same landing page at: urlhttps://doi.org/10.17170/kobra-202210116966 .

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Conflict of interest

The authors declare that they have no conflict of interest.

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