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# Determinants and Policy Ramifications of Cocoa Farmers' Use of Agrochemicals in Cocoa-Based (*Theobroma cacao*) Agroforestry Systems in Cameroon

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***Authors' contributions***

*This work was carried out in collaboration among all authors. All authors took an active part in the conception, data collection, data analysis, and write up. All authors read and approved the final manuscript.*

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## ABSTRACT

The application of agrochemicals in agroforestry systems in general and cocoa-based agroforestry systems in particular is unprecedented as agroforestry systems are considered as environmentally benign, agro-ecological and sustainable agricultural systems. It was within this context that this study was undertaken to examine the determinants of cocoa farmers' use of agrochemical in cocoa-based agroforestry systems. Through a mixed research approach, and data analysis using appropriate descriptive and inferential statistical tools, it was found that the main types of herbicides used by cocoa farmers in cocoa-based agroforestry systems are Paraquat (50%) and Glyphosate (40%). For fungicides, the main types used were Mancozeb (70%), Maneb (65%), Ridomil (60%), Caocobre (50%), and Nordox (40%). For insecticides, the main types used were

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Methyl (65%), Imidacloprid (60%), Endosulfan (50%), Cypermethrin (50%), and Fenobucarp (40%). The most common pests and diseases affecting cocoa perceived by cocoa farmers in cocoa-based agroforestry systems were Black pod – *Phytophtora spp* (100%), Capsid/Mirids – *Distantiella theobroma* and *Sahlbergella singularis* (100%), Cocoa Swollen Shoot Virus Disease – CSSVD (60%), Witches' broom – *Crinipellis perniciosa* (50%) and Vascular streak dieback (40%). Most cocoa farmers perceived that the use of all three agrochemicals (herbicides, fungicides, and insecticides) in cocoa-based agroforestry systems have negative socio-economic and environmental impacts. From Spearman rank correlation and logistic regression coefficients, it was noticed that the main explanatory variables having a statistically significant direct non-cause-effect and cause-effect relationship ($p<0.05$) with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were gender, income, availability of agrochemicals, access to information, membership in farming groups, and access to extension services. Meanwhile the main explanatory variables having a statistically significant indirect or inverse non-cause-effect and cause-effect relationship ($p<0.05$) with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were farm size and number of farms. It is recommended that policy makers take a critical look at the different agrochemicals used by cocoa farmers as well as the determinants of their use when formulating policies geared towards ensuring the sustainable use of these agrochemicals in cocoa-based agroforestry systems.

*Keywords: Cocoa; cocoa farmers; agrochemicals; determinants, agroforestry; insecticides; pesticides; herbicides; Cameroon.*

## 1. INTRODUCTION

The abusive use of agrochemical chemicals in different agricultural systems across the world has attracted the attention of environmentalists, scientists and policy makers [1–3]. Farmers in a desperate bid to fight weed, pests and disease attacks have resorted to the use of different types of agrochemicals [4–6]. The rate and frequency of use of these agrochemicals is alarming as most farmers believe that the use of agrochemicals is the only way to ensure a bountiful harvest [7,8]. Pesticides, fungicides and insecticides are the most commonly use agrochemicals by farmers worldwide [1].

Agroforestry systems have often been seen as agro-ecological, climate-smart, environmentally benign, and sustainable farming systems [9–14]. However, in recent times, farmers practicing agroforestry have been involved in agrochemical application in order to fight weed, pests and diseases, and improve crop yields [4–5,15,16]. The application of these agrochemicals in agroforestry systems has serious repercussions on plant and soil fauna diversity, which in turn affects the sustainability of the entire system [13,17–23].

In Cameroon, the cocoa-based agroforestry system is a major type of agroforestry system practiced by cocoa farmers [15,24–27]. These cocoa agroforests are often characterized by excessive application of agrochemicals in order to combat pests and diseases as well as weed, with the sole goal being to improve cocoa yields [15,28]. Although some studies have been carried out identifying the different agrochemicals used by cocoa farmers in cocoa agroforests in Cameroon [15,28,29], little or nothing has been done to examine the determinants of cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems. This study took an in-depth look at this burning issue i.e. the determinants of cocoa farmers' use of agrochemicals in the littoral region of Cameroon. More precisely, the study was undertaken to: (1) Identify the different agrochemicals used by cocoa farmers in cocoa-based agroforestry systems; (2) Identify common pests and diseases perceived by cocoa farmers in cocoa-based agroforestry systems; (3) Examine farmers' perceptions of the socio-economic and environmental impacts of agrochemicals use in cocoa-based agroforestry systems; and (4) Assess the factors affecting cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems.

## 2. MATERIALS AND METHODS

### 2.1 Description of the Study Area

The study was undertaken in the administrative district of Melong found in Mungo division, littoral region of Cameroon Fig. 1. Melong administrative district is located between latitude

4°22' to 6°20' N and longitude 9°17' to 10°52' E. Melong falls within one of the agroecological and relief regions of Cameroon known as the Western Highlands. The Western Highlands of Cameroon is made up of the entire northwest and west regions as well as parts of the littoral and south west regions. It covers a surface area of over 50,000 $km^2$ and has a population of over 5 million inhabitants, making it one of the most densely populated agroecological zones in Cameroon. Agriculture is the predominant activity making the Western Highlands of Cameroon a major breadbasket of Cameroon and the central African sub-region [30].

Melong administrative district (the study area for this study) has a humid tropical climate characterized by two main season i.e. a short dry season and a long rainy season, and a mean annual temperature of about 25°C. The vegetation type is dominated by degraded forests and patches of savannah grassland. The soils are ferralitic, volcanic and andosols. Melong is drained by a dense network of streams and rivers taking their rise from the surrounding hills.

### 2.2 Sampling, Data Collection and Data Analysis

To attain the objectives of this study, both secondary and primary data were collected using a mixed research approach. For primary data collection, multiphase sampling technique was used.

The multiphase sampling procedure was used as applied by other studies [31–33]. The first phase involved the purposive selection of Melong administrative district owing the predominance of cocoa-based agroforestry systems (the target farming system of the study). Melong is one of the main cocoa producing areas in Cameroon. The second phase involved focus group discussions with cocoa farming groups and key informant interviews with resource persons like chiefs, local authorities, agricultural extension agents, and others. This was done in order to get a general overview of the functioning of cocoa-based agroforestry systems in Melong administrative district. The third phase involved household surveys during which 300 cocoa farmers were randomly sampled across different villages in Melong administrative district. All these different phases were done with the help of agricultural extension agents working in the study area.

Secondary data for the study were collected from different sources including archives of the district delegations for agriculture and rural development; environment, protection of nature and sustainable development; forestry and wildlife; different libraries especially the libraries of the Melong council and that of the University of Dschang; scientific articles, books and book chapters both online and offline; and consulting different websites on the internet. Secondary data were collected in order to complement data obtained through primary data and in order to better compare and contrast the findings of the study with the findings of other related research works undertaken elsewhere.

Primary data were collected through household surveys. The household surveys were conducted through the administration of semi-structured questionnaires to 300 randomly chosen cocoa farmers. The questionnaires were structured in such a way as obtain information on socio-economic attributes of cocoa farmers as well as their perceptions of the use of agrochemicals and its socio-economic and environmental impacts. Household surveys were complemented with focus group discussions, key informant interviews and direct field observations. Key informant interviews, focus group discussions and direct field observations were mainly undertaken to ascertain the realities on the ground and to verify cocoa farmers' perceptions gotten during household surveys.

Data analysis was done using Microsoft Excel 2007 and SPSS 17.0 software packages. Descriptive and analytical statistical tools were used. Descriptive statistics included charts, tables as well as percentage indices, while analytical were Spearman's rank correlation, chi-square test statistic, and logistic regression. Analytical statistics were used to ascertain the non-causal and causal relationships existing between socio-economic factors and cocoa farmers' application of agrochemicals in cocoa-based agroforestry systems.

## 3. RESULTS

### 3.1 Agrochemicals Used by Cocoa Farmers in Cocoa-Based Agroforestry Systems

Different types of agrochemicals broadly classified under insecticides, pesticides and herbicides are used by cocoa farmers in cocoa-based agroforestry systems Fig. 2.

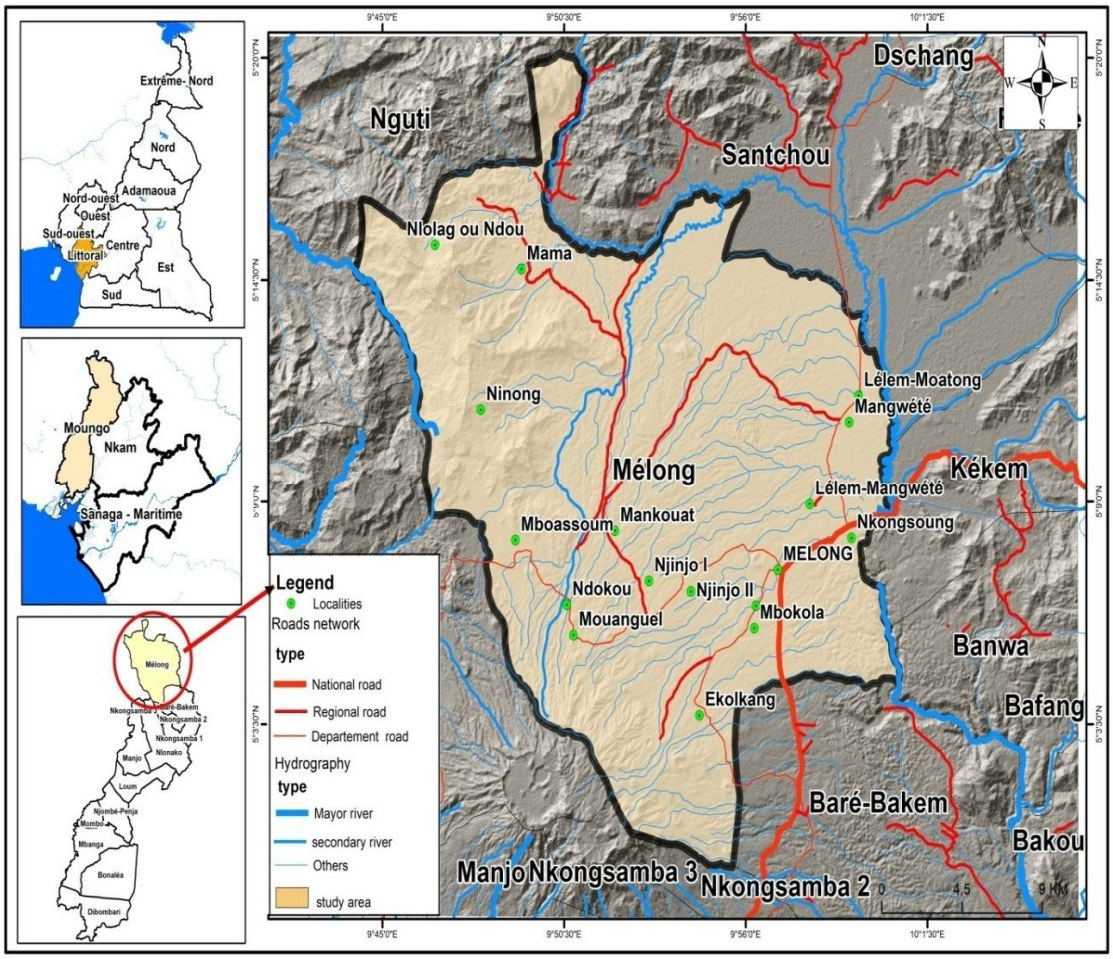


**Fig. 1. Map showing the study area**
*Source: Authors*

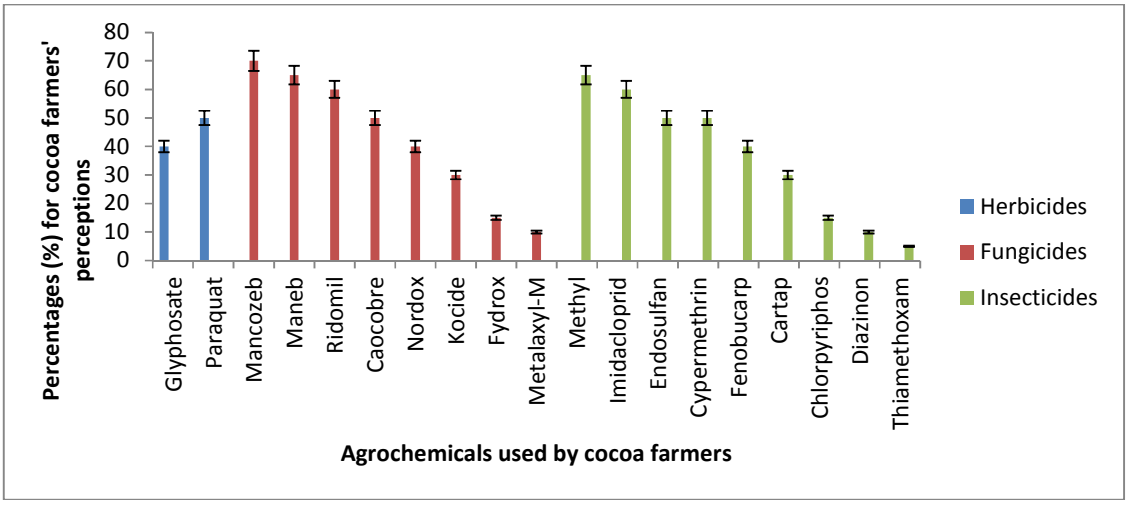


**Fig. 2. Agro-chemicals applied by farmers in cocoa-based agroforestry systems**

As shown on Fig. 2, the main types of herbicides used by cocoa farmers in cocoa-based agroforestry systems are Paraquat (50%) and Glyphosate (40%). For fungicides, the main types used were Mancozeb (70%), Maneb (65%), Ridomil (60%), Caocobre (50%), and Nordox (40%). For insecticides, the main types used were Methyl (65%), Imidacloprid (60%), Endosulfan (50%), Cypermethrin (50%), and Fenobucarp (40%).

### 3.2 Common Pests and Diseases Affecting Cocoa Perceived by Cocoa Farmers in Cocoa-Based Agroforestry Systems

Different types of pests and diseases affecting cocoa in cocoa-based agroforestry systems were perceived by cocoa farmers Fig. 3.

From Fig. 3, it is seen that the most common pests and diseases affecting cocoa perceived by cocoa farmers in cocoa-based agroforestry systems were Black pod – *Phytophtora spp* (100%), Capsid/Mirids – *Distantiella theobroma* and *Sahlbergella singularis* (100%), Cocoa Swollen Shoot Virus Disease – CSSVD (60%), Witches' broom – *Crinipellis perniciosa* (50%) and Vascular streak dieback (40%).

### 3.3 Cocoa Farmers' Perceptions of the Socio-Economic and Environmental Impacts of Agrochemical Application in Cocoa-Based Agroforestry Systems

Cocoa farmers had different perceptions of the socio-economic and environmental impacts of agrochemical application in cocoa-based agroforestry systems: some perceiving that agrochemical use has positive socio-economic and environmental impacts while others perceived that agrochemical use has negative socio-economic and environmental impacts Table 1.

As shown on Table 1, most cocoa farmers perceived that the use of all three agrochemicals (herbicides, fungicides, and insecticides) in cocoa-based agroforestry systems have negative socio-economic and environmental impacts. For herbicides, 59.1% of the cocoa farmers sampled perceived that its use has mainly negative socio-economic and environmental impacts, while 40.9% perceived that the use of herbicides has positive socio-economic and environmental impacts. Chi-square test statistic ($X^2$ = 14.7, $p<0.05$) showed a statistically significant difference in cocoa farmers' perceptions of the socio-economic and environmental impacts of herbicide application in cocoa-based agroforestry systems.

Concerning fungicides, perceptions varied with respect to the type of fungicide used by cocoa farmers in cocoa-based agroforestry systems Table 1. Fungicides such as Caocobre, Ridomil, Maneb and Mancozeb were perceived by most cocoa farmers (27.3%, 32.3%, 33.3%, and 43% respectively) to have negative socio-economic and environmental impacts in cocoa-based agroforestry systems. While fungicides such as Nordox, Kocide, Fydrox and Metalaxyl-M were perceived by most cocoa farmers (26%, 15.3%, 8.3%, and 6.3% respectively) to have positive socio-economic and environmental impacts in cocoa-based agroforestry systems. Chi-square test statistic ($X^2$ = 21.54, $p<0.05$) revealed a statistically significant difference in cocoa farmers' perceptions of the socio-economic and environmental impacts of fungicide use in cocoa-based agroforestry systems.

For insecticides, it was found that cocoa farmers' perceptions equally varied with respect to the type of insecticide used by cocoa farmers in cocoa-based agroforestry systems Table 1. Concerning insecticides like Cypermethrin, Imidacloprid, Cartap, Chlorpyriphos, Diazinon and Thiamethoxam, most cocoa farmers (30.7%, 33%, 18%, 8.7%, 5.3% and 3% respectively) perceived that the use of these insecticides have negative socio-economic and environmental impacts in cocoa-based agroforestry systems. While for insecticides like Methyl, Endosulfan, and Fenobucarp, most cocoa farmers (35%, 35.3% and 23.3% respectively) perceived that the use of these insecticides have positive socio-economic and environmental impacts in cocoa-based agroforestry systems. Chi-square test statistic ($X^2$ = 34.79%, $p<0.05$) showed that cocoa farmers' perceptions of the socio-economic and environmental impacts of insecticides use in cocoa-based agroforestry systems were significantly different.

### 3.4 Factors Influencing Cocoa Farmers' Use of Agrochemicals in Cocoa-Based Agroforestry Systems

Spearman rank correlation and logistic regression coefficients showed the existence of a direct and indirect non-cause-effect and cause-

effect relationship between explanatory variables and cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems Table 2.

From Table 2, it is noticed that the main explanatory variables having a statistically significant direct non-cause-effect and cause-effect relationship ($p<0.05$) with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were gender, income, availability of agrochemicals, access to information, membership in farming groups, and

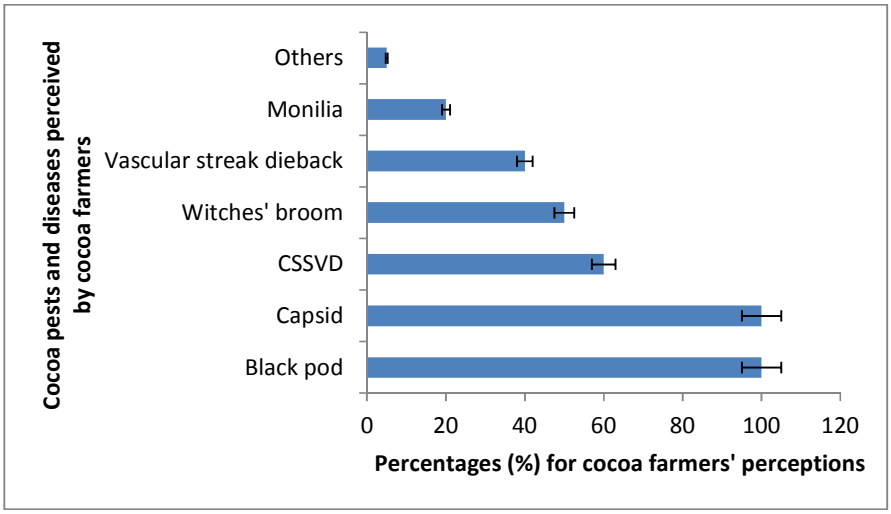


**Fig. 3. Farmer perceived pests and diseases attacking cocoa in cocoa-based agroforestry systems**

**Table 1. Socio-economic and environmental impacts of agrochemical application in cocoa-based agroforestry systems**

| Agrochemical | Socio-economic/Environmental impact of agro-chemical application | | | | $X^2$ | p-level |
|---|---|---|---|---|---|---|
| | Negative | | Positive | | | |
| Herbicides | Frequency | % | Frequency | % | | |
| Glyphosate | 26 | 23.6 | 18 | 16.4 | 14.17* | 0.048 |
| Paraquat | 39 | 35.5 | 27 | 24.5 | | |
| Fungicides | Frequency | % | Frequency | % | | |
| Nordox | 42 | 14 | 78 | 26 | | |
| Kocide | 44 | 14.7 | 46 | 15.3 | | |
| Caocobre | 82 | 27.3 | 68 | 22.7 | | |
| Ridomil | 97 | 32.3 | 83 | 27.7 | 21.54* | 0.000 |
| Fydrox | 20 | 6.7 | 25 | 8.3 | | |
| Maneb | 100 | 33.3 | 95 | 31.7 | | |
| Mancozeb | 129 | 43 | 81 | 27 | | |
| Metalaxyl-M | 11 | 3.7 | 19 | 6.3 | | |
| Insecticides | Frequency | % | Frequency | % | | |
| Methyl | 90 | 30 | 105 | 35 | | |
| Endosulfan | 89 | 29.7 | 106 | 35.3 | | |
| Cypermethrin | 92 | 30.7 | 58 | 19.3 | | |
| Imidacloprid | 99 | 33 | 81 | 27 | 34.79* | 0.000 |
| Fenobucarp | 50 | 16.7 | 70 | 23.3 | | |
| Cartap | 54 | 18 | 36 | 12 | | |
| Chlorpyriphos | 26 | 8.7 | 19 | 6.3 | | |
| Diazinon | 16 | 5.3 | 14 | 4.7 | | |
| Thiamethoxam | 9 | 3 | 6 | 2 | | |

** Significant at 5% probability level*

**Table 2. Factors affecting the use of agrochemicals by farmers in cocoa-based agroforestry systems**

| Explanatory variable | Correlation coefficient (r) | P-level | Logistic regression coefficient (B) | P-level |
|---|---|---|---|---|
| Age | 0.11 | 0.269 | 0.05 | 0.374 |
| Gender | 0.59* | 0.000 | 1.25* | 0.009 |
| Income | 0.74* | 0.000 | 2.62* | 0.000 |
| Availability of agro-chemicals | 0.50* | 0.000 | 1.18* | 0.018 |
| Farm size | -0.57* | 0.000 | -1.21* | 0.011 |
| Farm experience | 0.06 | 0.546 | 0.03 | 0.683 |
| Level of education | 0.03 | 0.608 | 0.001 | 0.719 |
| Number of farms | -0.52* | 0.000 | -1.19* | 0.014 |
| Household size | 0.09 | 0.307 | 0.14 | 0.414 |
| Access to information | 0.50* | 0.000 | 1.17* | 0.026 |
| Access to credit | 0.14 | 0.211 | 0.07 | 0.356 |
| Membership in farming group | 0.55* | 0.000 | 1.18* | 0.024 |
| Access to extension services | 0.68* | 0.000 | 2.04* | 0.000 |
| Likelihood ratio Chi-square | | | 136.97 | 0.000 |
| Nagelkerke $R^2$ | | | 0.482 | |
| Number of observations | | | 300 | |

** Significant at 5% probability level*

access to extension services. Meanwhile the main explanatory variables having a statistically significant indirect or inverse non-cause-effect and cause-effect relationship ($p<0.05$) with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were farm size and number of farms.

## 4. DISCUSSION

### 4.1 Agrochemicals Used by Cocoa Farmers in Cocoa-Based Agroforestry Systems

Different types of agrochemicals broadly classified under insecticides, pesticides and herbicides are used by cocoa farmers in cocoa-based agroforestry systems. The main types of herbicides used by cocoa farmers in cocoa-based agroforestry systems are Paraquat and Glyphosate. For fungicides, the main types used were Mancozeb, Maneb, Ridomil, Caocobre, and Nordox. For insecticides, the main types used were Methyl, Imidacloprid, Endosulfan, Cypermethrin, and Fenobucarp. Cocoa farmers' use of all these agrochemicals could be attributed to their relatively high income levels, easy access to the agrochemicals, availability of information on these agrochemicals, their membership in farming groups where information sharing on these agrochemicals is common; and the presence of agricultural extension agents who keep cocoa farmers abreast of the latest agrochemicals in the market. Studies have shown that farmers use different types of agrochemicals to control pests and diseases in their farms [1,3,6,29,30,34–37].

### 4.2 Common Pests and Diseases Affecting Cocoa Perceived by Cocoa Farmers in Cocoa-Based Agroforestry Systems

Different types of pests and diseases affecting cocoa in cocoa-based agroforestry systems were perceived by cocoa farmers. The most common pests and diseases affecting cocoa perceived by cocoa farmers in cocoa-based agroforestry systems were Black pod – *Phytophtora spp,* Capsid/Mirids – *Distantiella theobroma* and *Sahlbergella singularis*, Cocoa Swollen Shoot Virus Disease – CSSVD, Witches' broom – *Crinipellis perniciosa* and Vascular streak dieback. The recurrence of these pests and diseases in cocoa-based agroforestry systems could be attributed to the poor farming agricultural systems most cocoa farmers are increasingly resorting to such as cocoa monocultures, with little or no tree cover. In Cameroon, just a few studies have assessed the pests and diseases affecting cocoa agroforests [15,28,38]. The findings of this study will therefore add much to literature.

### 4.3 Cocoa Farmers' Perceptions of the Socio-Economic and Environmental Impacts of Agrochemical Application in Cocoa-Based Agroforestry Systems

Cocoa farmers had different perceptions of the socio-economic and environmental impacts of agrochemical application in cocoa-based agroforestry systems: some perceiving that agrochemical use has positive socio-economic and environmental impacts while others perceived that agrochemical use has negative socio-economic and environmental impacts. Overall, most cocoa farmers perceived that the use of agrochemicals (herbicides, fungicides, and insecticides) in cocoa-based agroforestry systems have negative socio-economic and environmental impacts. The fact that a majority of the sampled cocoa farmers perceived that the use of agrochemicals in cocoa-based agroforestry systems has mainly negative socio-economic and environmental impacts could be attributed to the fact that most of these cocoa farmers spend a lot of money to buy these agrochemicals to use in their cocoa farms, but the yields are never good enough to cover the cost of purchasing the agrochemicals. Equally, cocoa farmers have seen the level of soil fertility in their cocoa-agroforestry systems drop tremendously owing to their frequent application of these agrochemicals. The drop in soil fertility resulting from the application of agrochemicals could be caused by the toxic nature of most or all of these agrochemicals which harms soil organisms – the engineers working day and night to maintain levels of soil fertility in cocoa-based agroforestry systems. Studies carried out on different agricultural systems (cocoa-based agroforestry systems inclusive) [2,4–5,7,8,15,16,39,40,41,42], have generally shown that the socio-economic and environmental impacts of agrochemical application are negative.

### 4.4 Factors Influencing Cocoa Farmers' Use of Agrochemicals in Cocoa-Based Agroforestry Systems

The main explanatory variables having a statistically significant direct non-cause-effect and cause-effect relationship with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were gender, income, availability of agrochemicals, access to information, membership in farming groups, and access to extension services. This implies that an increase in male farmers, income, availability of agrochemicals, access to information, membership in farming groups, and access to extension services leads to an increase in the use of agrochemicals in cocoa-based agroforestry systems. This could be attributed to the fact that male farmers have more resources than their female counterparts; farmers with more income are able to buy more agrochemicals than their resource poor counterparts; the availability of agrochemicals pushes cocoa farmers to go for them; access to information allows farmers to make informed decisions of the agrochemicals they wish to use; membership in farming groups permits farmers to share vital information on different types of agrochemicals; and access to extension services permits cocoa farmers to ask pertinent questions as to how the agrochemicals are used which increases their propensity to use the agrochemicals in their cocoa-based agroforestry systems.

Meanwhile the main explanatory variables having a statistically significant indirect or inverse non-cause-effect and cause-effect relationship with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were farm size and number of farms. This implies that as the farm size and number of farms increases, cocoa farmers' propensity to use agrochemicals in their cocoa-based agroforestry systems reduces. This could be attributed to the fact that large farm sizes and many farms are difficult to manage. The financial and material cost involved in managing large farm sizes and many farms cannot be borne by many cocoa farmers who are resource poor and mostly lead a hand-to-mouth existence.

In Cameroon and across the tropics, few studies have examined the determinants of cocoa farmers' application of agrochemicals in their cocoa-based agroforestry systems. However, studies carried out on other farming systems like that of Nkemleke [43], on market gardening farming systems in south west Cameroon; and that of Fan et al. [44], on farming systems in Northern China showed that different determinants affect farmers' use of agrochemicals.

## 5. CONCLUSION

The application of agrochemicals in agroforestry systems in general and cocoa-based agroforestry systems in particular is

unprecedented as agroforestry systems are considered as environmentally benign, agro-ecological and sustainable agricultural systems. It was within this framework that this study was undertaken to examine the determinants of cocoa farmers' use of agrochemical in cocoa-based agroforestry systems. It was found that the main types of herbicides used by cocoa farmers in cocoa-based agroforestry systems are Paraquat and Glyphosate. For fungicides, the main types used were Mancozeb, Maneb, Ridomil, Caocobre, and Nordox. For insecticides, the main types used were Methyl, Imidacloprid, Endosulfan, Cypermethrin, and Fenobucarp. The most common pests and diseases affecting cocoa perceived by cocoa farmers in cocoa-based agroforestry systems were Black pod, Capsid/Mirids, Cocoa Swollen Shoot Virus Disease, Witches' broom and Vascular streak dieback. Most cocoa farmers perceived that the use of all three agrochemicals (herbicides, fungicides, and insecticides) in cocoa-based agroforestry systems have negative socio-economic and environmental impacts. The main explanatory variables having a statistically significant direct non-cause-effect and cause-effect relationship with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were gender, income, availability of agrochemicals, access to information, membership in farming groups, and access to extension services, implying that an increase in these variables leads to in the use of agrochemicals in cocoa-based agroforestry systems. Meanwhile the main explanatory variables having a statistically significant indirect or inverse non-cause-effect and cause-effect relationship with cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were farm size and number of farms, implying as these variables increase, cocoa farmers' use of agrochemicals reduces. It is therefore recommended that policy makers take a critical look at the different agrochemicals used by cocoa farmers as well as the determinants of their use when formulating policies geared towards ensuring the sustainable use of these agrochemicals in cocoa-based agroforestry systems.

## 6. POLICY RAMIFICATIONS

The following policy implications emerge from this study:

The main types of herbicides used by cocoa farmers in cocoa-based agroforestry systems were Paraquat and Glyphosate. For fungicides, the main types used were Mancozeb, Maneb, Ridomil, Caocobre, and Nordox. For insecticides, the main types used were Methyl, Imidacloprid, Endosulfan, Cypermethrin, and Fenobucarp. Thus, policies geared towards reducing the reducing the use of these agrochemicals should focus on these over-used agrochemicals.

The most common pests and diseases affecting cocoa perceived by cocoa farmers in cocoa-based agroforestry systems were Black pod – *Phytophtora spp*, Capsid/Mirids – *Distantiella theobroma* and *Sahlbergella singularis*, Cocoa Swollen Shoot Virus Disease – CSSVD, Witches' broom – *Crinipellis perniciosa* and Vascular streak dieback. Policies should be formulated that target these common cocoa diseases.

Most cocoa farmers perceived that the use of all three agrochemicals (herbicides, fungicides, and insecticides) in cocoa-based agroforestry systems have negative socio-economic and environmental impacts. Policies geared towards reducing the use of agrochemicals in cocoa agroforests should put in place in order to reduce the negative socio-economic and environmental impacts of these agrochemicals in cocoa-based agroforestry systems.

The main factors directly influencing cocoa farmers' use of agrochemicals in cocoa-based agroforestry systems were gender, income, availability of agrochemicals, access to information, membership in farming groups, and access to extension services. Policies geared towards reducing the use of agrochemicals in cocoa-based agroforestry systems should lay emphasis on these factors.

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## COMPETING INTERESTS

Authors have declared that no competing interests exist.

## REFERENCES

1. Utomo B, Prawoto AA, Bonnet S, Bangviwat A, Gheewala SH.

Environmental performance of cocoa production from monoculture and agroforestry systems in Indonesia. Journal of Cleaner Production. 2016;134:583–591.

2. Oyekale AS. Cocoa farmers' compliance with safety precautions in spraying agrochemicals and use of personal protective equipment (PPE) in Cameroon. International Journal of Environmental Research and Public Health. 2018;15(2): 327.
3. Borden KA, Isaac ME. Management strategies differentially affect root functional trait expression in cocoa agroforestry systems. Agronomy for Sustainable Development. 2019;39(2):21.
4. Danso-Abbeam G, Setsoafia ED, Ansah IGK. Modeling farmers' investment in agrochemicals: The experience of smallholder cocoa farmers in Ghana. Research in Applied Economics. 2014; 6(4):1.
5. Danso-Abbeam G, Baiveaunhi LJS. Adoption of agrochemical management practices among smallholder cocoa farmers in Ghana. African Journal of Science, Technology, Innovation and Development. 2017;9(6):717–728.
6. Ogunjimi SI. Farmers' knowledge level of precautionary measures in agro-chemicals usage on cocoa production in Osun and Edo States, Nigeria. International Journal of Agriculture and Forestry USA; 2012.
7. Mokwunye IU, Babalola FD, Ndagi I, Idrisu M, Mokwunye FC, Asogwa EU. Farmers' compliance with the use of approved cocoa pesticides in cocoa producing states of Nigeria. Journal of Agriculture and Social Sciences. 2012;12(2):44–60.
8. Jepson PC, Guzy M, Blaustein K, Sow M, Sarr M, Mineau P. Measuring pesticide ecological and health risks in West African agriculture to establish an enabling environment for sustainable intensification. Philos Trans R Soc Lond Ser B Biol Sci 2014;369(1639):20130491–20130491.
9. Jose S. Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 2009; 76:1–10.
10. Nair PKR. Agroforestry systems and environmental quality: Introduction. Journal of environmental quality. 2011;40(3):784–790.
11. Jose S. Agroforestry for conserving and enhancing biodiversity. Agroforestry Systems. 2012;85:1–8.
12. Leakey RRB. Socially modified organisms in multifunctional agriculture - addressing the needs of smallholder farmers in Africa. Arch Crop Sci. 2017;1(1):20-29.
13. Awazi NP, Tchamba NM. Enhancing agricultural sustainability and productivity under changing climate conditions through improved agroforestry practices in smallholder farming systems in sub-Saharan Africa. African Journal of Agricultural Research. 2019;14(7):379-388.
14. Leakey RRB. A holistic approach to sustainable agriculture: trees, science and global society. In: Mosquera-losada, M.R. and Prabhu, R. (eds.), Agroforestry for sustainable agriculture, Burleigh Dodds Science Publishing, Cambridge, UK; 2019. (ISBN: 978 1 78676 220 7; www.bdspublishing.com).
15. Sonwa DJ, Coulibaly O, Weise SF, Adesina AA, Janssens MJJ. Management of cocoa: Constraints during acquisition and application of pesticides in the humid forest zones of Cameroon. Crop Protection. 2008;27(8):1159–1164.
16. Jagoret P, Snoeck D, Bouambi E, Ngnogue HT, Nyasse S, Saj S. Rehabilitation practices that shape cocoa agroforestry systems in Central Cameroon: Key management strategies for long term exploitation. Agroforestry Systems. 2018;92:1185–1199.
17. Mortimer R, Saj S, David C. Supporting and regulating ecosystem services in cocoa agroforestry systems. Agroforestry Systems. 2018;92:1639–1657.
18. Villanueva-Lopez G, Lara-Perez LA, Oros-Ortega I, Ramirez-Barajas PJ, Casanova-Lugo F, Ramos-Reyes R. Diversity of soil macro-arthropods correlates to the richness of plant species in traditional agroforestry systems in the humid tropics of Mexico. Agriculture, Ecosystems and Environment. 2019;286:106658.
19. Suarez LR, Josa YTP, Samboni EJA, Cifuentes EHDB, Salazar JCS. Soil macro-fauna under different land uses in the Colombian Amazon. Pesquisa Agropecuaria Brasileira. 2018;53:1383–1391.
20. Suarez LR, Audor LCU, Salazar JCS. Formation of macroaggregates and organic carbon in cocoa agroforestry systems. Floresta e Ambiente. 2019;26(3).
21. Marsden C, Martin-Chave A, Cortet J, Hedde M, Capowiez Y. How agroforestry

systems influence soil fauna and their functions – a review. Plant and Soil. 2020; 453:29–44.

22. Cardinael R, Mao Z, Chenu C, Hinsinaer P. Belowground functioning of agroforestry systems: Recent advances and perspectives. Plant and Soil. 2020;1-13.
23. Wartenberg AC, Blaser WJ, Gattinger A, Roshetko JM, Van Noordwijk M, Six J. Soil fertility and theobroma cacao growth and productivity under commonly intercropped shade-tree species in Sulawesi, Indonesia. Plant and Soil. 2020;453:87–104.
24. Sonwa DJ, Nkongmeneck AB, Weise SF, Tchatat M, Adesina AA, Janssens MJ. Diversity of plants in cocoa agroforests in the humid forest zone of southern Cameroon. Biodivers Conserv. 2007;16:2385–2400.
25. Jagoret P, Michel-Dounais I, Malezieux E (2011). Long term dynamics of cocoa agroforests: a case study in central Cameroon. Agroforestry Systems 81: 267 – 278.
26. Jagoret P, Michel-Dounias I, Snoeck D, Ngnogue HT, Malezieux E. Afforestation of savannah with cocoa agroforestry systems: A small-farmer innovation in central Cameroon. Agroforestry Systems. 2012;86:493–504.
27. Jagoret P, Kwesseu J, Messie C, Michel-Dounias I, Malezieux E. Farmers' assessment of the use value of agro-biodiversity in multispecies systems. An application to cocoa agroforests in Central Cameroon. Agroforestry Systems. 2014;88:983–1000.
28. Tankou CM. The Cameroon cocoa story. The "Supply Change – Make Supermarkets fair" project sponsored by the European Union; 2015.
29. Mahob RJ, Ndoumbe-Nkeng M, Ten Hoopen GM, Dibog L, Nyasse S, Rutherford M. Pesticides use in the cocoa sector in Cameroon: Characterization of supply source, nature of active ingredients, fashion and reasons for their utilization. International Journal of Biological and Chemical Sciences. 2014;8(5):1976–1989.
30. Tankou CM, de Snoo GR, Persoon G, de longh HH. Evaluation of smallholder farming systems in the Western Highlands of Cameroon. IOSR Journal of Engineering. 2017;7(1):1–11.
31. Awazi NP, Tchamba NM. Determinants of small-scale farmers' adaptation decision to climate variability and change in the north-west region of Cameroon. African Journal of Agricultural Research. 2018;13(12):534–543.
32. Awazi NP, Tchamba NM, Avana TML. Climate change resiliency choices of small-scale farmers in Cameroon: Determinants and policy implications. Journal of Environmental Management. 2019;250: 109560.
33. Awazi NP, Tchamba NM, Temgoua LF. Enhancement of resilience to climate variability and change through agroforestry practices in smallholder farming systems in Cameroon. Agroforest Syst. 2020;94:687-705.
    Available:https://doi.org/10.1007/s10457-019-00435-y
34. Alemagi D, Duguma L, Minang PA, Nkeumoe F, Feudjio M, Tchoundjeu Z. Intensification of cocoa agroforestry systems as a REDD+ strategy in Cameroon: Hurdles, motivations, and challenges. International Journal of Agricultural Sustainability. 2015;13(3):18–203.
35. Pouokam GB, Album WL, Ndikontar AS, Sidatt MEH. A pilot study in Cameroon to understand safe uses of pesticides in agriculture, risk factors for farmers' exposure and management of accidental cases. Toxics. 2017;5:30.
36. Van Vliet JA, Giller KE. Mineral nutrition of cocoa: A review. Advances in Agronomy. 2017;141:185–270.
37. Mukete N, Li Z, Mukete B, Bobyeg P. Cocoa production in Cameroon: A socio-economic and technical efficiency perspective. International Journal of Agricultural Economics. 2018;3(1):1–8.
38. Asogwa EU, Dongo LN. Problems associated with pesticide usage and application in Nigerian cocoa production: A review. African Journal of Agricultural Research. 2009;4(8):675–683.
39. Kenko ND, Asanga BF, Ngameni TN, Mbida M. Environmental and Human Health Assessment in Relation to Pesticide Use by Local Farmers and the Cameroon Development Corporation (CDC), Fako Division, South-West Cameroon. European Scientific Journal. 2017;13(21):1857-7881.
40. Kimengsi JN, Tosam JN. Climate variability and cocoa production in Meme Division of Cameroon: Agricultural development policy

options. Greener Journal of Agricultural Sciences. 2013;3(8):606–617.
41. Nkamleu GB, Keho Y, Gockowski J, David S. Investing in agrochemicals in the cocoa sector in Cote d'Ivoire: hypotheses, evidence, and policy implications. AfJARE. 2007;1(2).
42. Oyekale AS. Cocoa farmers' compliance with safety precautions in spraying agrochemicals and use of personal protective equipment (PPE) in Cameroon. International Journal of Environmental Research and Public Health. 2018;15(2): 327.
43. Nkemleke EE. Assessing Small-Scale Farmers' Attitudes, Practices and Vulnerability to Pesticides Use in Market Gardening Crops in M'muockngie (South Western Cameroon). Journal of Advances in Education and Philosophy. 2019;4(6): 295-305.
44. Fan L, Niu H, Yang X, Qin W, Bento CPM, Ritsema CJ, Geissen V. Factors affecting farmers' behavior in pesticide use: Insights from a field study in northern China. Science of the Total Environment. 2015; 537:360–368.



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