Journal of Economics, Finance and Management Studies

ISSN (print): 2644-0490, ISSN (online): 2644-0504

Volume 5 Issue 08 August 2022

Article DOI: 10.47191/jefms/v5-i8-01, Impact Factor: 6.274

Page No. 2098-2112

The Use of Fuzzy Logic to Measure Multidimensional Poverty in Cameroon

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ABSTRACT: The protean nature of poverty does not make it easy to understand, as it is a concept that can be seen from several angles (sociological, anthropological and economic). However, the aim of this paper is to provide a measure of multidimensional poverty in Cameroon. In other words, to make a multidimensional analysis of poverty. To achieve this, the fuzzy logic approach of Lotfi Zadeh (1965) would be ideal, as it appears to be the appropriate tool for specifying such vague concepts as poverty.

Using the third Cameroonian household survey (ECAM3), we were able to identify the different poverty groups. This enabled us to construct a multidimensional poverty index in three stages. First, the non-monetary dimensions were selected, then the deprivation indicators were extracted and finally the results were aggregated.

Because of the calculations, the fuzzy poverty index in Cameroon is 0.6010. This indicates that 60.10% of Cameroonian households are structurally poor. Disaggregating this index by region, stratum and gender of the head of household, shows that the Far North region has the highest fuzzy proportion *(P=0.7367)*, while the two major metropolises of Yaoundé and Douala have better scores. For the most part, rural areas are the poorest with a fuzzy proportion of *(0.7463),* while female-headed households are the most indigent *(P=0.6264)*.

Analysis of the deprivation indicators shows, however, that the supply of drinking water *(0.7657), the* mode of disposal of wastewater *(0.9501), the* level of education of heads of households *(0.7430)* and household income *(0.9051)* are those that accentuate the poverty of Cameroonian households. Of the ten regions of Cameroon, the Far North *(0.1585),* the North West *(0.1452)* and the West *(0.1161)* are those that contribute most to poverty.

KEYWORDS: *Fuzzy subsets/Fuzzy logic, Membership functions, Fuzzy measures of poverty, Poverty decomposition, Deprivation indicators, Totally fuzzy and relative approach.*

INTRODUCTION

Reading the many articles and books on poverty, we get the impression that all the issues have already been addressed in this area. However, according to the ATD Fourth World research institute, 2.8 billion people live on less than 2 dollars a day, i.e. almost half the world's population, and 448 million children are underweight. These figures alone show that the phenomenon remains current. It can even be said to be heteromorphic and evolving over time. Its measurement and definition have always raised questions among researchers for decades and two approaches have often been confronted. The traditional one, based on the unidimensionality of poverty, and the other, on its multidimensionality. Nevertheless, this extension of the meaning of poverty has raised many questions and criticisms. According to Kanbur and Squire (1999), the extension of the meaning of poverty does not modify the scope of poor individuals, because the dimensions retained are much related and according to these authors, income has an impact on all of them. This calls into question the multidimensional approach. However, according to Cerioli and Zani (1990, pp. 272-284), measuring poverty by taking income alone provides only a partial picture of the phenomenon of poverty. Vero, in fact, finds that "the traditional approach to poverty is questionable, as it is presented as an *'all or nothing'* formulation, i.e. *'is poor'* or *'is not poor'*[1] ". The legitimisation of such an approach says nothing about the degree of poverty. Thus, not everyone agrees in setting a poverty line in view of the diversity that exists[2]. In addition, it leads to a significant loss of information (Betti & Cheli, 2001). Therefore, because of these various oppositions, the question arises: "*Is it useful to measure poverty from a*

[1] Josiane Vero and Patrick Werquin (1998), A Re-examination of the Measurement of Poverty, Economie et Statistique n° 308-309-310, pp. 143-158.

[2] Hagenaaers has identified different poverty lines that can be classified into several categories, depending on whether one considers poverty as an absolute, relative or subjective concept (see Miceli, 1997)

multidimensional perspective that goes beyond unidimensional measures, both individually and collectively? Assessing such a highly subjective notion automatically leads to imprecise results, where there is a lack of clarity, with an increased presence of vagueness. On the contrary, progress has been made by developing an instrument for imprecision based on the theory of fuzzy subsets, the foundation of fuzzy logic[3] , an extension of the theory of classical subsets, in which important mathematical developments have been undertaken. One can thus quote the works of the American school with Lotfi A. Zadeh, the Romanian school with G. C. Moisil and the French school with A. Kaufman who introduced it in France in 1973[4] . The use of this approach will make it possible to facilitate gradations in the membership of a component to a category. In other words, to allow a component to belong more or less to this category.

I. Approach methodological

Predominantly monetary poverty has often been determined based on an equilibrium point called the threshold. The latter allows us, as in Boolean logic, to divide a population into two sub-groups: the poor and the non-poor. However, as mentioned in the introduction, several researchers do not agree on this principle and consider that the transition from a state of deprivation to a state of non-privation is gradual. Consequently, this requires the creation of a membership function for deprived individuals, defined in a range where one could systematically integrate or reject individuals, but which at its limit values, varies proportionally with the neighbourhood of the group *(Vero & Werquin, 1977)*. The advantage of this principle is that it combines the financial situation and the general conditions of existence in which individuals are situated.

1. Blurred proportions of indigence

Let us assume N the total population consists of n citizens or households$(i = 1,2, \dots, n)$. The fuzzy subset P of the indigent of N is characterised as the set of pairs:

$$\mathrm{P} = \{(i, \mu_P(i)), i \in N\} \qquad [1]$$

Where, $\mu_P(i)$ is the degree to which any household *i* belongs to the fuzzy subset of the indigent population. This allows us to recompose the formula as follows[5] :

$$\begin{cases} \mu_P(i) = 0 \\ 0 < \mu_P(i) < 1 \\ \mu_P(i) = 1 \end{cases} \qquad [2]$$

Where, μ_P *(i)* = 0 if household *i* is not definitely indigent;

$0 < \mu_P(i) < 1$ if household *i* is incompletely indigent; and $\mu_P(i) = 1$ if household *i is* fully indigent.

1.1. Proportions entirely unclear

The first authors to apply fuzzy subset theory to poverty were Cérioli and Zani (1990). Their approach was called ***the Totally Fuzzy Approach (TFA)***. The idea is to determine the degree to which each household belongs to the subset of the poor, using a group of relevant deprivation indicators. These indices of deprivation were classified into three main types of variables: dichotomous qualitative, polytomous qualitative and continuous quantitative.

a) *Dichotomous qualitative variables*

To characterise this type of variable, by the possession or not of a durable good such as the possession of a refrigerator, let us suppose a population of n citizens or households:

$(i = 1,2, \dots, n)$ and are k dichotomous satisfaction indicators $(l = 1, \dots, k_d)$. For example, D_l the subset of citizens or households deprived of the $l - i\grave{e}me$ property. In addition, let $d_l = d_{1l}, \dots d_{il}, \dots, d_{nl}$ be the dichotomous value interpreting the possession regulation with respect to this good: d_{il} takes a zero value when the household i does not have the good l and a value equivalent to 1 in the opposite case. Thus, to illustrate this specific case, the membership function of the fuzzy subset for each household i in the population is stated as:

$$\mu_{D_l} = \begin{cases} 0, si\ d_{il} = 1 \\ 1, si\ d_{il} = 0 \end{cases} \qquad [3]$$

Clearly, D_l is not a fuzzy subset. In other words, in the specific case of dichotomous variables, the membership function of the fuzzy subset of the indigent is interpreted as a conventional membership to a classical set.

b) Polytomous categorical variables

These are those with more than two modalities, each of which refers to some degree of deprivation. To characterise the membership function, the modalities can be arranged in ascending order with respect to the risk of deprivation. Consider the subset O_l of households or individuals expected to be in a state of deprivation whose degree is expressed as l where $l = 1, \dots, k_0$

[3] Fuzzy logic is a multivalued logic in which the truth values of the variables, instead of being true or false, are real numbers between 0 and 1.
[4] ("Introduction to the theory of fuzzy subsets. I. - Éléments théoriques de base", Editions Masson et Cie).
[5] In this trivariate logic, the second case is the most interesting

. Let us note $o_l$such that $o_l = o_{1l}, \dots, o_{il}, \dots o_{nl}$is the polytomous variable for estimating the degree of deprivation for each individual or household. Let us denote $\theta^{(m)} = (\theta_l^{(1)}, \dots, \theta_l^{sl})$with $m = 1, \dots, s_l$the possible s_l possible modalities of the variable $o_l$ordered in such a way that increasing values of m denote an increase in deprivation. We can then add scores $\psi_l^{(m)}$ with $m = 1, \dots, s_l$ to the multiple ordered modalities $\theta_l^{(m)}$. This allows us to form the following link between these multiple scores:

$$\psi_l^{(1)} < \cdots < \psi_l^{(m)} < \cdots < \psi_l^{(sl)} \quad [4]$$

In an easier way, things, scores take the value of the first s_l first integers. This is illustrated as follows:

$$\psi_l^{(m)} = m \text{ with } m = 1, \dots, s_l \quad [5]$$

Seen from this angle, let us assume that the modalities are equidistant if we associate the degrees of deprivation with them. Taking into account the ordinal nature of the variable o_l we choose the value $o_l = o_{lmin}$ below which it is agreed that there is no more deprivation, and at the other boundary a value o_{lmax} that clearly indicates a state of indigence. Assuming that we associate the values $o_{l\,min}$ and $o_{l\,max}$ the respective scores $\psi_{l\,min}$ and $\psi_{l\,max}$the following membership function emerges:

$$\mu_{o_l} = \begin{cases} 0 & si\ \psi_{il} \le \psi_{l\,min} \\ \frac{\psi_{il} - \psi_{l\,min}}{\psi_{l\,max} - \psi_{l\,min}} & si\ \psi_{l\,min} < \psi_{il} < \psi_{l\,max} \\ l & si\ \psi_{il} \ge \psi_{l\,max} \end{cases} \quad [6]$$

Statement [5] shows that the degree of membership in the fuzzy subset of indigents increases proportionally to the neighbourhood of indigency.

c) *Continuous variables*

On this type of variable, income or expenditure, which are quantitative values, are recorded. Faced with the difficulty of obtaining a unanimously agreed threshold of indigence, Cerioli and Zani were undecided. Their reflections led to the use of two thresholds: the first noted x_{min}which represents the value below which a citizen is obviously considered indigent, and the second, noted x_{max}which represents the value of the variable above which a citizen is obviously not indigent. Of these two values, the membership function takes values between 0 and 1 as specified in the interval [0,1] and is regressive in the specific case of income or expenditure. In reality, one imagines that an increase in income is interpreted as an improvement in the satisfaction situation. Let us assume a subset χ_l of citizens or households exhibiting an adverse state according to the $l - ième$ variable, with $l = 1, \dots, k_x$. Let on the other hand, $x_l = x_{1l}, \dots, x_{il}, \dots, x_{nl}$ be the continuous variable allowing estimating the deprivation. The membership function can then take the following general form:

$$\mu_{\chi_l}(i) = f(x_{il}) \quad [7]$$

Assuming that the risk of destitution is assumed to fluctuate linearly between $x_{l\,min}$ and $x_{l\,max}$the membership function can be written as follows[6] :

$$\mu_{\chi_l}(i) = \begin{cases} 1 & si\ 0 \le x_{il} \le x_{l\,min} \\ \frac{x_{l\,max} - x_{il}}{x_{l\,max} - x_{l\,min}} & si\ x_{l\,min} \le x_{il} \le x_{l\,max} \\ 0 & si\ x_{il} > x_{l\,max} \end{cases} \quad [8]$$

1.2. Totally fuzzy and relative approach

Cheli and Lemmi (1995) have identified two drawbacks[7] to Cerioli and Zani's approach. The first disadvantage concerns the fanciful nature of the constitution of the two indigence thresholds $x_{l\,min}$ and $x_{l\,max}$. The second drawback relates to the use of a linear membership function that relies on the questionable assumption of equidistance between the multiple modalities. These researchers have suggested a procedure that allows us to go beyond the two disadvantages and which they have called Totally Fuzzy Relative (TFR). Firstly Totally Fuzzy, because it avoids the characterisation of the critical lower and upper thresholds. Finally Totally Relative, because the degree of deprivation of each citizen or household for a given index will depend on their position in the index distribution.

Assume the set of Ξ_j of citizens or households that experience deprivation relative to the index j. In other words, $\xi_j = \xi_{ij}, \dots, \xi_{nj}$the variable interpreting the deprivation status of n citizens or households in comparison to the index $j$with $j = 1, \dots, k$ and $k = k_d + k_o + k_x$. Cheli and Lemmi characterise two membership functions[8] , taking into account the risk that indigence or deprivation may increase as a result of an increase or decrease in the value obtained by the variable ξ_j. According to the first scheme, we have the following membership function:

$$\mu_{\Xi_j}(i) = F_j(\xi_{ij}) \quad [9]$$

[6] The difficulty here is how to determine the values of *xl* min and *xl* max in a meaningful way

[7] For further details see Cheli and Lemmi (1995), Cheli et *alii* (1994)

[8] Both functions (23) and (24) fit perfectly into a relative conception of poverty, as they are defined by taking into account the relative position of each individual with respect to all individuals (see Aouni & *alii* for more details).

Concerning the scheme, the membership function corresponds to a complement of the first scheme:

$$\mu_{\Xi_j}(i) = 1 - F_j(\xi_{ij}) \quad [10]$$

With F_j which is nothing more than the distribution function of the variable ξ_j. However, the above two membership functions are inadequate when using discrete-valued deprivation indices. Thus, they offer a standardised version of the membership function (Miceli, 1997).

Consider $\xi_j^{(m)}$, $m = 1, \dots, s_j$ the multiple modalities of the variable $\xi_j$ranked in ascending order, taking into account the risk of indigence. In such a way that, $\xi_j^{(1)}$ is the minimum risk of destitution and $\xi_j^{(s_j)}$constitutes the maximum risk of destitution linked to the index of deprivation j. It is then possible to characterise the degree of membership of the fuzzy subset as follows:

$$\mu_{\Xi_j}(i) = \begin{cases} 0 & si\ \xi_{ij} = \xi_j^{(1)} \\ \mu_{\Xi_j}\left(\xi_j^{(m-1)}\right) + \frac{F_j\left(\xi_j^{(m)}\right) - F_j\left(\xi_j^{(m-1)}\right)}{1 - F_j\left(\xi_j^{(1)}\right)} & si\ \xi_{ij} = \xi_j^{(m)}\ \ m > 1 \end{cases} \quad [11]$$

With, $\mu_{\Xi_j}(\xi_j^{(m-1)})$ which corresponds to the degree of membership in the fuzzy subset Ξ_j of a citizen whose variable ξ_j obtains the modality$(m-1)$, the modalities of the variable ξ_j being arranged in ascending order with respect to the danger of indigence**.**

2. Aggregate indices of deprivation

It is now a question of calculating the degree to which each household belongs to the $\mu_P(i)$ of each household to the fuzzy set P of the poor. In other words, it is a question of reducing to one dimension, the degrees of membership acquired from the multiple indices. Chiappero-Martinetti (1994) notes that one could globally perform an aggregation intervention[9] through a function h: $[0,1]^k$ for $k \geq 2$so that:

$$\mu_P(i) = h[\mu_{\Xi_1}(i), \mu_{\Xi_2}(i), \dots, \mu_{\Xi_k}(i)] \quad [12]$$

Where, $\Xi_1, \Xi_2, \dots, \Xi_k$, are the k fuzzy subsets calculated on the k indigence indices. Let us mention that there remain at least two possibilities to characterise the function h. The first possibility could be to obtain the union of the fuzzy sets, i.e. to estimate equation [12] and thus to characterise h such that a maximum function:

$$\max[\mu_{\Xi_1}(i), \mu_{\Xi_2}(i), \dots, \mu_{\Xi_k}(i)]$$

In this framework, a household is characterised as totally deprived to the extent that it expresses complete deprivation in at least one index of deprivation. A second possibility would be to consider the intersection of the fuzzy sets and for this purpose, to obtain the following equation, characterising h to the example of the minimum function: $\min\left[\mu_{\Xi_1}(i), \mu_{\Xi_2}(i), \dots, \mu_{\Xi_k}(i)\right]$. In this second scheme, a household is considered totally deprived only if it is in a position of absolute deprivation with respect to all the indices of deprivation.

However, both of these contingencies represent obstacles (Miceli, 1997). In the main eventuality, two citizens are similarly valued, with one being deprived on a single index of deprivation, and the other being deprived on all indices. In the second case, one is led to grant a similar degree of belonging to citizens or households with dissimilar living standards. In order to remedy these obstacles, it is therefore urged to broaden the aggregation method, thus allowing the function h to obtain intermediate values between the minimum and the maximum, thus interpreting the interaction possibilities between the multiple deprivation indices (Miceli, 1997). Considering that deprivation must be considered as an accumulation of disadvantages, one-way to take this need into account is to use the aggregation of mean interventions in such a way that the continuum disparity is controlled (Chiapperro-Martinetti, 1994):

$$\min\left[\mu_{\Xi_1}(i), \dots, \mu_{\Xi_k}(i)\right] \leq h\left[\mu_{\Xi_1}(i), \dots, \mu_{\Xi_k}(i)\right] \leq \max\left[\mu_{\Xi_1}(i), \dots, \mu_{\Xi_k}(i)\right] \quad [13]$$

A h is generally associated with a minimal axiomatic structure verifying the axioms of monotonicity, continuity and symmetry (Aouni, Bettabar & Belmokadem, 2002). A category of operators satisfying the conditions of this axiomatic structure can be stated as the generalized average of the membership degrees:

$$h_\delta\left[\mu_{\Xi_1}(i), \dots, \mu_{\Xi_k}(i)\right] = \left[\sum_{j=1}^{k} \omega_j \left(\mu_{\Xi_j}(i)\right)^\delta\right]^{1/\delta}, \quad \delta \neq 0 \quad [14]$$

δ is a coefficient[10] which helps to define the type of average. Among others, when $\delta \longrightarrow 0$a geometric mean is obtained, when $\delta = -1$, a harmonic mean is obtained. When the coefficient $\delta = 1$the result is nothing but an arithmetic mean. In the formulation

[9] Aggregation can occur at different levels. We can distinguish between aggregation at the level of each individual or aggregation at the level of indicators that are themselves aggregated. These two options are in fact two possible ways of obtaining a global synthetic index (Fusco, 2005).

[10] δ Also determines the level of substitution between the deprivation indicators. Specification type (28) corresponds to the constant elasticity of substitution (CES) function class.

[14], ω_j corresponds to the weights specifying the relative importance to be attributed to each satisfaction index. We have $\omega_j \geq 0$ and $\sum_{j=1}^{k} \omega_j = 1$. Cérioli and Zani offered a statement of the membership function $\mu_p(i)$ with $\delta = 1$:

$$\mu_p(i) = \sum_{j=1}^{k} \omega_j \mu_{\Xi_j}(i) \qquad [15]$$

They proposed the use of the following weighting method:

$$\omega_j = \frac{ln\left(1/\bar{\mu}_{\Xi_j}\right)}{\sum_{j=1}^{k} ln\left(1/\bar{\mu}_{\Xi_j}\right)} \qquad [16]$$

The above formula can thus be rewritten as follows:

$$\omega_j = \frac{\ln(\bar{\mu}_{\Xi_j})}{\sum_{j=1}^{k} \ln\left(\bar{\mu}_{\Xi_j}\right)} \qquad [17]$$

With, $\bar{\mu}_{\Xi_j} = 1/n \sum_{i=1}^{n} \mu_{\Xi_j}(i)$ which is the fuzzy proportion of indigent households according to the index of deprivation ξ_j. It could thus be shown that each ω_j is a reciprocal function of the average degree of deprivation in the population according to the index ξ_j and the use of the logarithm is excellently justified since more weight is given to indices of deprivation interpreting the less perpetual signs of deprivation (Micel, 1997).

In a similar way and in direct relation to expression [11], Cheli and lemmi (1995) define ω_j as follows:

$$\omega_j = ln\left(1/n \sum_{j=1}^{k} \mu_{\Xi_j}\right) \qquad [18]$$

It can be noted that the expression of Cheli and Lemmi (1995) coincides with that of Cerioli and Zani (1990) in the situation of binary parameters. Some authors such as Pi Alperin & al (2005) have suggested taking into account in Cerioli and Zani's weight system the administrative expenses of the State for any index:

$$\omega_j = \frac{ln\left(1/\bar{\mu}_{\Xi_j}\right)\times(1+d_{jr})}{\sum_{j=1}^{k} ln\left(1/\bar{\mu}_{\Xi_j}\right)\times(1+d_{jr})} \qquad [19]$$

With d_{jr} is the proportion of social public expenditure, for the $j-i\grave{e}me$ indicator as a proportion of total public social expenditure. r, represents the data used. If the information concerns public social expenditure for the whole country then $r-1$. Assuming that the information is exploited by region, then $r = 1, \dots, t$ in order to differentiate the various regions of the country (t being the number of regions in the country). According to Pi Alperin et al. integrating the public social expenditure of the state means that the weight associated with each index increases by reflecting the administrative benefit for it; without this index for an individual, partly financed by the state, the value of the associated weight must be greater than that of the indices where it is absent.

Regarding the criticisms, Vero & Werquin (1997) questioned the correctness of Cerioli and Zani's weighting system and noted that, in their ultimate demonstration of the accumulation of deprivations[11] . They conclude that such a calculation raises the question of the multi-colinearity of non-monetary indices and their subordination to income. Closely related indices reveal the risk of over-representation of a specific dimension in the aggregate membership function (Vero, 2006). They then offered a new compensation for the weighting of two seriously related disadvantages; this leads to a lowering of the weight of overabundant indices. Let us estimate n citizens or households; that is k deprivation indices ($j = 1, \dots, k$). Let us mention by μ_{ij} the degree to which the citizen belongs to the fuzzy subset of the indigent i according to the index of deprivation j. We have: $\forall i$ and $\forall j$, $\mu_{ij} \in [0,1]$. When all appearances of indigence are taken into account, a citizen i is defined by his vector of k degrees of membership μ_{ij}such that $\mu_i = (\mu_1, \dots, \mu_j, \dots, \mu_k)$. The degrees of membership in the fuzzy subset of indigents of each citizen according to any index of deprivation constitute the matrix $\prod_{n\times k}$ below:

$$\prod_{n\times k} = \begin{pmatrix} \mu_{11}, \dots, \mu_{1j}, \dots, \mu_{1k} \\ \dots, \dots, \dots, \dots, \dots \\ \mu_{i1}, \dots, \mu_{ij}, \dots, \mu_{ik} \\ \dots \quad \dots \quad \dots \quad \dots \quad \dots \\ \mu_{n1}, \dots, \mu_{nj}, \dots, \mu_{nk} \end{pmatrix}$$

Let us now estimate $f_i$the percentage of citizens benefiting more or as much from deprivation as the citizen i on each estimated index. In order to construct the aggregate membership function for the fuzzy subset of the destitute, it suffices first to proportion an intermediate membership measure to the destitute clan $m_p(i)$:

[11] The degree of membership of the fuzzy subset of the poor is higher the more disadvantages are added to each other. Thus, the weight associated with two deprivations such as the lack of a shower and hot water is greater than the weight assigned to the lack of hot water alone. It is equal to the sum of the two weights taken in isolation. Thus, the accumulation is taken into account in the membership function by simply adding the elementary deprivations (Véro, 2002).

$$m_p(i) = \begin{cases} \frac{\ln\left(1/f_i\right)}{\sum_{i=1}^{n}\left(1/f_i\right)} & si\ 0 < f_i \leq 1 \\ 0 & si\ f_i = 0 \end{cases} \quad [20]$$

The weighting related to the membership degree vector of μ_i is similar to $\ln\left(1/f_i\right)$. The more generalised a vector of goods is, conversely, the weighting related to the deprivation of this set of practices will be necessary. In order to have the aggregate membership function, the intermediate aggregate membership calculation must be normalised and centred. Thus, we have:

$$\mu_p(i) = \begin{cases} \frac{m_p(i) - min[m_p(i)]}{max[m_p(i)] - min[m_p(i)]} & f_i > 0 \\ 0 & f_i = 0 \end{cases} \quad [21]$$

2.1. The multidimensional indicator of indigence

The multidimensional approach based on the principle of fuzzy sets helps to characterise an indicator of indigence in relation to all households. We will now look at how to construct this indicator. Subsequently, it will be noted that this indicator can be disaggregated and this disaggregation can be done by clan and by deprivation index. This helps to characterise the reasons for formal indigence, and consequently to construct socio-economic policies aimed at reducing the phenomenon of poverty (Pi Alperin, Seyte & Terraza, 2005).

2.2. Development of a global indicator of indigence

The calculation of the degree of indigence of each citizen or household having been carried out, we now have the capacity to elaborate an indicator of indigence for all households. This indicator can be characterised as the arithmetic mean of the household membership functions (Cérioli & Zani, 1994):

$$P = \frac{1}{n}\sum_{i=1}^{n} \mu_p(i) \quad [22]$$

With $P \in [0,1]$. If we note by $|P| = \sum_{i=1}^{n} \mu_p(i)$the cardinal of the set P of the poor

Is formulated as follows: $P = \frac{|P|}{n}$

The coefficient P is the percentage of households in the fuzzy subset of indigents. The parameter $P = 0$ under the condition that $\mu_p(i) = 0$ regardless of the citizen or household, i.e. in the complete absence of indigence. $P = 1$ Under the condition that $\mu_p(i) = 1$ regardless of the citizen or household, i.e. in situations of extreme destitution. The most usual situation is that where $0 < P < 1$ in other words P is an increasing function of the degree of indigence of any citizen or household. Finally, note that P can be expressed as a weighted average of the degrees of deprivation of the population of *n* individuals or households for each indicator and thus:

$$P = \sum_{j=1}^{k} \bar{\mu}_{\Xi_j} \times \omega_j \quad [23]$$

The indigence indicator *P* presented in expression [22] has the characteristic of decomposability and belongs to the class of additively decomposable indigence indicators [(Chakravarty, Mukherjee & Ranade, 1983), (Foster, Greer & Thorbecke, 1984)]. Moreover, *P* is estimated as an extrapolation of the **"Head Count Ratio[12] "** by restricting to a single index of deprivation offered by income and that the totality of the indigent P is not blurred.

2.3. Disaggregation of the multidimensional indigence indicator

A disaggregation of the multidimensional indicator of deprivation is incorporated, which combines the role of groups of inhabitants and the dimensions of deprivation in the interpretation of overall deprivation (Mussard & Pi Alperin, 2005). This leads the authorities to characterise the reasons for indigence and to become formally involved in reducing it.

i) Disaggregation by group

This disaggregation helps to focus the groups most affected by destitution.

Let's break down the entire economic area into q groups G_q of size $n_q (q = 1, \dots, s)$.

The intensity of indigence of the $i - ème$ citizen or household of $G_q$as follows:

$$\mu_p\left(i_q\right) = \sum_{j=1}^{k} \mu_{\Xi_j}(i_q) \times \omega_j \quad [24]$$

The multidimensional indigence indicator attached to the group G_q group is as follows:

$$P_q = \frac{1}{n_q}\sum_{i=1}^{n_q} \mu_p(i_q) \quad [25]$$

According to [24], P is determined as a weighted average of the degree of indigence within the group itself:

$$P = \frac{1}{n}\sum_{q=1}^{s}\sum_{i=1}^{n_q} \mu_p(i_q) \quad [26]$$

It is therefore possible to determine the contribution of the q-th group to the total indigence indicator. Hence:

[12] Head Count Ratio (HCR) is the proportion of a population that exists or lives below the poverty line.

$$C_p^q = \frac{1}{n}\sum_{i=0}^{n_q} \mu_p(i_q) \quad [27]$$

ii) Disaggregation by index of deprivation

It is possible to integrate the disaggregation by deprivation index by showing that it is easy to determine the contribution of the $j - ième$ deprivation indicator to the total indigence index (Dagum & Costa, 2004). Thus, the (absolute) contribution of the $j - ième$ deprivation indicator to the multidimensional poverty index is written as:

$$C_p^j = \bar{\mu}_{\Xi_j} \times \omega_j \quad [28]$$

Based on the statement [27], we can determine the contribution of the $j - ième$ index of deprivation to the $q - ième$ group. We thus obtain the following expression:

$$C_{P_q}^j = \bar{\mu}_{\Xi_j}^q \times \omega_j \quad [29]$$

With:

$$\bar{\mu}_{\Xi_j}^q = \frac{1}{n_q}\sum_{i=1}^{n_q} \mu_{\Xi_j}(i_q) \times \omega_j$$

This disaggregation helps to provide more data on the dimensions of destitution and to refine the study in the establishment of appropriate socio-economic policies aimed at alleviating destitution.

iii) Multidimensional disaggregation

The indicator is disaggregated P by group and by deprivation index.

Thus, according to equation [29] we can deduce P as follows:

$$P = \sum_{q=1}^{s}\sum_{j=1}^{k} \mu_{\Xi_j}(i_q) \times \omega_j \quad [30]$$

In this way, it is clear that P thus manifests itself as a weighted function of the unidimensional indicators of the *j*-th deprivation index in the *q*-th group. Therefore, the participation of the *j*-th deprivation index of the *q -group* in the general indigence indicator is formulated as follows:

$$C_P^{j_q} = \bar{\mu}_{\Xi_j}(i_q) \times \omega_j \quad [31]$$

Synchronous disaggregation proposes all possible arrangements (indicators/groups) that contribute to the situation of deprivation on the economic surface (Mussard & Pi Alperin, 2005) and all essential information aimed at reducing deprivation is contained in these arrangements.

II. Measuring multidimensional poverty in Cameroon: the use of fuzzy logic.

1. Measuring multidimensional poverty

The idea here is to make a multidimensional analysis of poverty, using fuzzy measurement. The advantage of this approach is that it includes the monetary character and the general conditions of existence in which households live. In order for this empirical phase to make sense, the use of the third Cameroonian household survey (ECAM 3[13]) was necessary.

To obtain a fuzzy measure of multidimensional poverty, three steps are essential. First, the choice of non-monetary dimensions *(we chose eight (8): education, health, drinking water, housing, sanitation, energy, communication and employment)*. From these dimensions, we then extracted fifteen or so indicators of deprivation and finally aggregated the results.

1.1. Deprivation indicators

Between Cheli et *al* (1994) and Cheli and Lemmi (1995), there is a debate on the choice of deprivation indicators. According to the latter, the choice of deprivation indicators is crucial in this type of research, as each indicator reveals a particular aspect of poverty. Furthermore, they recommend distinguishing between effect variables such as the possession of durable goods, and those that cause poverty[14] such as unemployment. Miceli (1997) agrees, finding that the choice of indicators of deprivation is delicate and cannot be made without a dose of arbitrariness. He believes that fuzzy measurement is dictated by the availability of data.

That said, the indicators of deprivation used in our study are as follows:

1. Assessment of current health status ;
2. Main mode of drinking water supply ;
3. Main source of lighting ;
4. Main source of energy for cooking ;
5. Method of waste disposal ;
6. Mode of wastewater disposal ;

[13] ECAM 3 is the third Cameroonian household survey conducted by the National Institute of Statistics (INS) in 2007.

[14] The analysis could then be carried out separately for the two types of variables. Unfortunately, in this paper we have not followed this route.

7. Type of toilet facility ;
8. Main wall material ;
9. Main roof material ;
10. Main soil material ;
11. Presence of radio ;
12. Presence of the television ;
13. Poverty status of the household according to the interviewer ;
14. Household income situation ;
15. Level of education of the head of the household.

Two types of indicators are distinguished here:

- Dichotomous *(i.e. two-mode)* and
- Polytomous *(multi-modality)* indicators. The modalities of these variables were ordered by increasing degree of deprivation *(see equation [4])*, and then the membership function w a s used *(see equation [6])*.

In sum, we identified two (2) dichotomous indicators and thirteen (13) polytomous or multinomial indicators.

The degree of deprivation for each household is determined from equation [8], proposed by Cerioli and Zani. However, in this formulation, $\boldsymbol{x_{lmin}}$ and $\boldsymbol{x_{lmax}}$ represent, respectively, the lower and the upper poverty line.

1.2. Unclear measure of poverty in Cameroon

Table I below presents the fuzzy poverty measure for all households $\boldsymbol{P}$ for all households and the fuzzy proportions of poor households $\overline{\boldsymbol{\mu}}_{(\xi_j)}$ for each deprivation indicator. The value $\boldsymbol{P}$ equal to 0.6010 means that 60.10% of Cameroonian households are structurally poor. The proportion of poor households $\overline{\boldsymbol{\mu}}_{(\xi_j)}$ varies from 0.1334, reflecting low deprivation in terms of the main roofing material, to a maximum of 0.9501, reflecting rather high deprivation in terms of sewage disposal. In this table we note that poverty in terms of sanitation is among the most widespread with ($\overline{\boldsymbol{\mu}}_{(\xi_5)} = \boldsymbol{0,7654}$, $\overline{\boldsymbol{\mu}}_{(\xi_6)} = \boldsymbol{0,9501}$ and $\overline{\boldsymbol{\mu}}_{(\xi_7)} = \boldsymbol{0,5652}$).

It should be noted that 76.57% of households are deprived of drinking water. Consequently, they obtain their water from undeveloped water points ($\overline{\boldsymbol{\mu}}_{(\xi_2)} = \boldsymbol{0,7657}$). With regard to household lighting, only 56.61% are lit by the company in charge of electricity distribution ($\overline{\boldsymbol{\mu}}_{(\xi_3)} = \boldsymbol{0,5661}$). In terms of housing, 35.93% ($\overline{\boldsymbol{\mu}}_{(\xi_{10})} = \boldsymbol{0,3593}$) of households have covered the floor of their house with at least cement. In terms of communication, 60.07% of households do not have a television set and 47.34% do not have a radio ($\overline{\boldsymbol{\mu}}_{(\xi_{12})} = \boldsymbol{0,6007}$ and $\overline{\boldsymbol{\mu}}_{(\xi_{11})} = \boldsymbol{0,4734}$). Finally, according to ***Table I***, 79.33% of households are poor ($\overline{\boldsymbol{\mu}}_{(\xi_{13})} = \boldsymbol{0,7933}$).

Table I: Fuzzy Poverty in Cameroon

Deprivation indicator		**Unclear proportion of poor households**
$\boldsymbol{j}$	ξ_j	$\bar{\mu}(\xi_j)$
1	Assessment of current health status	0,2373
2	Main mode of drinking water supply	0,7657
3	Main source of lighting	0,5661
4	Main source of energy for the kitchen	0,5295
5	Method of waste disposal	0,7654
6	Method of wastewater disposal	0,9501
7	Type of toilet facility	0,5652
8	Main wall material	0,6275
9	Main roof material	0,1334
10	Main soil material	0,3593
11	Presence of radio	0,4734
12	Presence of the television set	0,6007

13	Poverty status of the household according to the interviewer	0,7933
14	Household income situation	0,9051
15	Education level of the head of household	0,7430
P Unclear measure of poverty		**0,6010**

Source: Calculated by the author.

1.3. Decomposition of fuzzy poverty in Cameroon

To give depth to the analysis made above, the decomposition of the fuzzy poverty measure is essential. In this paper, we have chosen mainly and arbitrarily to make three decompositions: the decomposition of poverty by regions[15] , by milieu/zone and by gender of the head of household. However, several other decompositions have been made to better understand the phenomenon of poverty. We can thus cite the decomposition according to the size and composition of the household, the decomposition according to socio-economic groups or the age of the heads of household.

1.3.1. Breakdown of fuzzy poverty by regions and cities

After calculating the fuzzy measure of poverty obtained by aggregating the 15 deprivation indicators, a partial examination of ***Table II*** allows us to make a comparison of the relative position of each region and metropolis. Thus, the fuzzy proportion of poor households is highest in the Far North region of Cameroon ($\boldsymbol{P = 0,7367}$)followed by the North region $\boldsymbol{P = 0,6934}$). The North-West comes third ($\boldsymbol{P = 0,6750}$) followed by the East ($\boldsymbol{P = 0,6555}$). The Centre region ranks fifth ($\boldsymbol{P = 0,6366}$)Adamaoua is sixth ($\boldsymbol{P = 0,6340}$)The West region ranks seventh ($\boldsymbol{P = 0,6189}$)the Littoral the eighth ($\boldsymbol{P = 0,6022}$)South West is ninth ($\boldsymbol{P = 0,5880}$), the South the tenth ($\boldsymbol{P = 0,5556}$)and the two major metropolises of Yaoundé and Douala, respectively eleventh ($\boldsymbol{P = 0,4137}$) and the twelfth ($\boldsymbol{P = 0,4023}$). This ranking may seem natural if one takes into account the unequal distribution of socio-economic infrastructures between the different regions and the two major cities. It is even noticeable that the latter are relatively close, given the small disparity between their blurred proportions of poverty. Another comparison shows that the fuzzy proportion of these two metropolises is lower than the national average. This implies that the best living conditions exist in these two large cities. The analysis of the indicators by region and city confirms the above ranking and provides more arguments for the understanding of multidimensional poverty.

Table II: Breakdown of fuzzy poverty by regions and cities

Regions[16]	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**	**(9)**	**(10)**	**(11)**	**(12)**	**(13)**
Deprivation indicator ξ_j	**Unclear proportion of poor households $\overline{\mu}_{(\xi_j)}$**												**Set**
1	0,3441	0,2172	0,1364	0,3492	0,1618	0,1477	0,4113	0,1643	0,1322	0,3341	0,3009	0,1482	**0,2373**
2	0,5805	0,7280	0,7271	0,7148	0,8259	0,7518	0,7347	0,8836	0,8529	0,7828	0,7813	0,8249	**0,7657**
3	0,2698	0,3963	0,6649	0,6621	0,6150	0,6756	0,5353	0,6132	0,7125	0,5232	0,5159	0,6092	**0,5661**
4	0,2136	0,1430	0,4838	0,7211	0,5418	0,4972	0,6371	0,5233	0,8846	0,5853	0,5376	0,5849	**0,5295**
5	0,2097	0,2808	0,9447	0,9610	0,9610	0,9353	0,8618	0,9263	0,8198	0,7025	0,8037	0,7782	**0,7654**
6	0,8475	0,9080	0,9516	0,9912	0,9727	0,9777	0,9262	0,9534	0,9905	0,9590	0,9645	0,9584	**0,9501**
7	0,2145	0,2603	0,5095	0,5251	0,6916	0,9015	0,4725	0,8823	0,6694	0,6700	0,4766	0,5095	**0,5652**

Sources: Calculations by the author

[15] The 10 regions of Cameroon, plus the two major metropolitan areas of Yaoundé and Douala.

[16] (1) : Douala - (2) : Yaoundé - (3) : Adamaoua - (4) : Centre - (5) : East - (6) : Far North - (7) : Littoral - (8) : North - (9) : North West - (10) : West - (11) : South - (12): South West

8	0,2650	0,3806	0,8411	0,6708	0,7002	0,7707	0,5840	0,8538	0,7335	0,6924	0,5065	0,5308	**0,6275**
9	0,0029	0	0,2452	0,0389	0,2709	0,4187	0,0220	0,4256	0,0830	0,0193	0,0168	0,0580	**0,1334**
10	0,0753	0,0528	0,3610	0,4422	0,4157	0,7545	0,3093	0,5317	0,4406	0,4266	0,2449	0,2574	**0,3593**
11	0,4100	0,3659	0,4231	0,3505	0,5690	0,7493	0,4270	0,4903	0,5891	0,4436	0,3458	0,5173	**0,4734**
12	0,2850	0,2368	0,6477	0,6708	0,6610	0,8503	0,6389	0,8098	0,7004	0,6442	0,4654	0,5979	**0,6007**
13	0,8284	0,8444	0,8117	0,8191	0,7768	0,7559	0,7739	0,7930	0,7556	0,7852	0,8187	0,7565	**0,7933**
14	0,8875	0,8738	0,8860	0,8982	0,9114	0,9413	0,8979	0,8810	0,9413	0,9273	0,8860	0,9289	**0,9051**
15	0,6006	0,5176	0,8756	0,7337	0,7581	0,9224	0,8006	0,6702	0,8192	0,7882	0,6691	0,7599	**0,7430**
P_q	**0,4023**	**0,4137**	**0,6340**	**0,6366**	**0,6555**	**0,7367**	**0,6022**	**0,6934**	**0,6750**	**0,6189**	**0,5556**	**0,5880**	**0,6010**

After observing the calculations presented in the table above, the Far North region is structurally the poorest in Cameroon, unlike Douala, which is the least poor. Despite this, it is important to know where the pockets of poverty actually lie. The segmentation of regions and metropolises is necessary because on the one hand, we have the cities and on the other, the villages. Thus, the following section will help us to better locate the pockets of poverty through a stratification by urban, semi-urban and rural areas.

1.3.2. Decomposition of fuzzy poverty by Urban, Semi-urban and Rural strata.

In a similar way to the previous analysis, we will compare the relative position of each stratum in terms of the value of the fuzzy poverty measure obtained by aggregating the 15 deprivation indicators. It is immediately apparent that the fuzzy proportion of poor households is higher in rural areas ($P = 0{,}7463$)with the semi-urban area occupying the intermediate position ($P = 0{,}5805$), the urban area has the lowest fuzzy proportion of poor households ($P = 0{,}4761$).

When we look at the deprivation indicators individually, we notice that households living in rural areas have a much better health status than those living in urban and semi-urban areas *(21.85% deprivation rate in rural areas, compared to 23.63% in urban areas and 27.71% in semi-urban areas)*. It should be pointed out that this is the only indicator where such a difference can be observed. The same is true when analysing the data obtained from the second indicator in our ***Table III, i***.e. "the mode of supply of drinking water". According to this indicator, the semi-urban area has a better rate of deprivation than the urban and rural areas [*(67.65%)* of deprivation in semi-urban areas; *(73.93%)* of deprivation in urban areas and *(85.23%)* in rural areas].

When we analyse the remaining 14 indicators, excluding the one dealing with household health status, we find that rural households are disadvantaged in all aspects. It can be seen that households living in rural areas are disadvantaged in all aspects and that 13 of the 15 indicators show that households living in urban areas have the best living conditions.

When analysing the data from ***Table III, it can be*** seen that Cameroonian households have a serious problem with drinking water supply. The fuzzy proportion in urban areas is *(0.7393)*, in semi-urban areas *(0.6765)* and in rural areas *(0.8579)*.

Households as a whole are deprived of infrastructure for the evacuation of wastewater, the different rates of deprivation show that *(98.24%)* of households living in rural areas discharge their wastewater in nature, against *(95.46%)* in semi-urban areas and *(92.14%)* in urban areas.

In semi-urban and rural areas, households dispose of *(83.25%)* and *(91.38%)* of their rubbish in nature respectively.

The data in ***Table III*** clearly show that poverty is much more entrenched in rural areas than in semi-urban or urban areas. Therefore, the design of different poverty reduction policies should be more oriented towards households living in rural areas.

Table III: Breakdown of fuzzy poverty by stratum (Urban; Semi-urban; Rural)

Stratum	Urban (1)	Semi-Urban (2)	Rural (3)	(4)
Deprivation Indicator ξ_j	Unclear proportion of poor households $\overline{\mu}_{(\xi_j)}$			Set
1	0,2363	0,2471	0,2185	**0,2373**
2	0,7393	0,6765	0,8579	**0,7657**
3	0,4256	0,5435	0,7316	**0,5661**
4	0,2648	0,5215	0,8523	**0,5295**
5	0,5812	0,8325	0,9138	**0,7654**
6	0,9214	0,9546	0,9824	**0,9501**
7	0,3590	0,5672	0,8688	**0,5652**
8	0,4015	0,6207	0,8605	**0,6275**
9	0,0114	0,0715	0,3571	**0,1334**
10	0,1531	0,2676	0,6773	**0,3593**
11	0,3715	0,4016	0,6473	**0,4734**
12	0,3865	0,6025	0,8633	**0,6007**
13	0,6792	0,7268	0,8936	**0,7933**
14	0,8822	0,9031	0,9412	**0,9051**
15	0,6385	0,7222	0,8985	**0,7430**
P_q	**0,4761**	**0,5805**	**0,7463**	**0,6010**

Source: Calculated by the author

1.3.3. Decomposition of blurred poverty by gender of household head

We are now going to analyse the decomposition of fuzzy poverty of Cameroonian households according to the gender of the head of household. The results of this decomposition according to the 15 deprivation indicators, as well as the fuzzy poverty measure, are presented in ***Table IV*** below.

The observation that can be made from this table is that 13 out of 15 indicators contribute strongly to the better living conditions of male-headed households. Indeed, the fuzzy poverty measure for this group of households is 0.5838. This is lower than the national average *(0.6010)*.

Table IV: Fuzzy decomposition by gender of head of household

Gender of the head of household	Male (1)	Women (2)	(3)
Deprivation indicator ξ_j	Unclear proportion of poor households $\overline{\mu}_{(\xi_j)}$		Set
1	0,1876	0,2919	**0,2373**
2	0,7652	0,7732	**0,7657**
3	0,5507	0,5915	**0,5661**
4	0,5115	0,5375	**0,5295**
5	0,7674	0,7534	**0,7654**
6	0,9401	0,9621	**0,9501**
7	0,5725	0,5853	**0,5652**
8	0,6237	0,6356	**0,6275**
9	0,1496	0,0901	**0,1334**
10	0,369	0,4002	**0,3593**
11	0,4138	0,6159	**0,4734**
12	0,5863	0,6532	**0,6007**
13	0,7377	0,7857	**0,7933**
14	0,8961	0,9144	**0,9051**
15	0,7122	0,7975	**0,7430**
P_q	**0,5838**	**0,6264**	**0,6010**

Source: Calculated by the author.

If we look at poverty from a housing perspective, particularly in terms of the use of the main roof material, we see that female-headed households have lower average deprivation. The same observation can be partially made with regard to sanitation, and particularly on the method of disposal of household waste. On the other hand, examining poverty in the light of housing and specifically on the main material of the walls and the main material of the floor, shows, with one exception, that male-headed households enjoy the best housing conditions. If we now focus on poverty based on communication items, the presence of a radio or television set, we also find that male-headed households have lower average deprivation. The same observation can be made if we look at poverty as reflected in the education level of the household head.

2. Contribution by decomposition of regions, strata and deprivation indicators to national poverty

In this sub-section, the different contributions of regions, urban, semi-urban and rural strata, as well as poverty indicators to total poverty, will be presented.

2.1. Contribution to national poverty by region breakdown

This chapter cannot be concluded without shedding further light on the fuzzy analysis of poverty in Cameroon. It is therefore interesting to calculate the contribution of each of Cameroon's ten regions, plus the major metropolises of Douala and Yaoundé, to total poverty: Douala and Yaoundé, to total poverty. We have recorded the data in ***Table V*** below.

Table V: Contribution by Decomposition of the different regions

Decomposition		P_α	Absolute contribution	Relative contribution
Metropolises (Yaoundé and Douala) and Regions	Douala	0,4023	0,0371	0,0612
	Yaoundé	0,4137	0,0371	0,0613
	Adamaoua	0,6340	0,0322	0,0533
	Centre	0,6366	0,0445	0,0735
	East	0,6555	0,0338	0,0558
	Far North	0,7367	0,0959	0,1585
	Coastal	0,6022	0,0337	0,0557
	North	0,6934	0,0471	0,0778
	Northwest	0,6750	0,0879	0,1452
	West	0,6189	0,0703	0,1161
	South	0,5556	0,0261	0,0431
	South West	0,5880	0,0596	0,0985

Source: Calculations by the author

The analysis of ***Table V*** provides more information on the contributions to fuzzy poverty of each region according to the chosen indicators. It can be seen that the Far North region contributes the most to poverty in Cameroon with a rate of *(15.85%)*, followed by the North West *(14.52%)*, and the West *(11.61%)*. The South-West region comes fourth in this ranking with a rate of *(9.85%)*. The North region comes fifth with a contribution to poverty of *(7.75%)*, the Centre region is ranked sixth with a rate of *(7.35%)*. The region that contributes the least to fuzzy poverty is the South region with a rate of *(4.31%)*, followed by the Adamaoua region *(5.33%)*, the Littoral *(5.57%)* and the East *(5.58%)*. Yaoundé and Douala ranked seventh and eighth respectively with almost similar rates *(6.13%)* and *(6.12%)*.

2.2. Contribution by breaking down the different urban, semi-urban and rural strata

In this particular case, the data obtained after calculating the contributions in ***Table VI*** support the idea that poverty in Cameroon is largely located in the rural area, as this area contributes *41.22% in* relative terms, followed by the semi-urban area *(32.68%)* and the urban area *(26.16%)*. If we look at the data for the breakdown according to the gender of the head of household, we see that the gender of the head of household is the most important factor. Indeed, we can see that households headed by men make the greatest contribution to total poverty *(nearly 71.91%)*, although this type of household is not particularly affected by poor living conditions. The relatively large share of these households in the total also explains this.

Table VI: Contribution by strata breakdown: Urban, Semi-Urban and Rural

Decomposition		P_α	Absolute contribution	Relative contribution
Strata	Urban	0,4703	0,1568	0,2610
	Semi-urban	0,5888	0,1963	0,3268
	Rural	0,7428	0,2476	0,4122
Gender of head of household	Male	0,5838	0,4280	0,7191
	Woman	0,6264	0,1672	0,2810

Source: Calculated by the author.

2.3. Contribution of different deprivation indicators to national poverty by decomposition

These analyses cannot be concluded without presenting the calculations of the absolute and relative contributions of the deprivation indicators below in ***Table VII***. According to the results, we can see that the mode of rubbish disposal contributes the most to household deprivation, as we note a relative contribution of about *(10.54%)*. As stated in the previous analyses, the vast majority of households dispose of their waste in the open. This indicator is closely followed by the household income situation, which contributes *(10.04%)* to household deprivation. The poverty status of the household according to the interviewer is the third most important indicator contributing to household deprivation *(8.80%)*. The mode of supply of drinking water is the fourth most important indicator contributing to household deprivation with a relative contribution of *(8.49%)*. The mode of rubbish disposal is the fifth most important deprivation indicator contributing to household deprivation with a rate similar to the previous one: (*8.49%)*.

Table VII: Contribution of the different deprivation indicators by decomposition

Decomposition		ξ_j	Absolute contribution	Relative contribution
Fuzzy poverty indicators	1	0,2373	0,0158	0,0263
	2	0,7657	0,0510	0,0849
	3	0,5661	0,0377	0,0623
	4	0,5295	0,0353	0,0587
	5	0,7654	0,0510	0,0587
	6	0,9501	0,0633	0,1054
	7	0,5652	0,0377	0,0627
	8	0,6275	0,0418	0,0696
	9	0,1334	0,0089	0,0148
	10	0,3593	0,0239	0,0399
	11	0,4734	0,0316	0,0525
	12	0,6007	0,0400	0,0666
	13	0,7933	0,0529	0,0880
	14	0,9051	0,0603	0,1004
	15	0,7430	0,0495	0,0824

Source: Calculated by the author

CONCLUSION

The application of fuzzy subset theory to the measurement of poverty in Cameroon has led to a number of conclusions. The fuzzy index of poverty in Cameroon is equal to 0.6010, which means that 60.10% of Cameroonian households are structurally poor. Deprivation indicator will break down this measure by stratum, by region and by gender of the head of household. Looking at the results by deprivation indicator, we see that poverty in terms of sanitation *(mode of sewage disposal, mode of household waste disposal)*, income *(household income situation)*, and drinking water *(mode of drinking water supply)* are the most widespread in Cameroon. Analysis by stratum shows that the fuzzy proportion of poor households is highest in rural areas, with semi-urban areas occupying the intermediate position. The same examination of the fuzzy poverty index by region shows that the Far North is the region that contributes most to fuzzy poverty *(15.85%)*. The North West follows with *(14.52%)* and finally West Cameroon *(11.61%)*. However, the South region contributes the least to fuzzy poverty *(4.31%)*, followed by Adamaoua and Littoral *(5.33%* and *5.57%* respectively). If we look at this index according to the gender of the head of household, we see that households headed by w o m e n have a higher average level of deprivation.

All this range of consequences reveals the usefulness of measuring poverty from a multidimensional perspective. However, improving people's living conditions depends on the implementation of an inclusive development process that can be driven by decentralised local authorities, in order to significantly reduce the levels of deprivation indicated by most of the dimensions identified in this work.

Nevertheless, it should be noted that the fuzzy logic method has some disadvantages. First of all, the fact of expressing its knowledge in the form of rules in natural language (and therefore qualitative) does not make it possible to prove that the system will have an optimal behaviour. All these rules, which the programmer has to integrate into the system, are done in a completely ad-doc way. However, there is no guarantee that the system is stable.

To overcome these limits, we could in future work, move from fuzzy logic to fuzzy topology, as CHANG did in 1968 or, alternatively, make use of the possibility theory that Lotfi Zadeh first introduced in 1978 as an extension of fuzzy logic which was later developed by Didier Dubois and Henri Prade.

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