Application of Coase Theorem to Analyze the Welfare Gain and Loss in a Conflict of Herders' Damage in Croppers' Land at the Adamawa Region of Cameroon

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Abstract

By applying the Coase theorem, this paper attempts to solve a conflict of land management between croppers producing maize on land and herders who breed cattle that needs land to graze on in the Adamawa region of Cameroon. The results indicate that, the herders commit maximum damage when their cattle destroys 3 tons/ha of maize and a compromise is reached when 1.2 tons/ha of crops are damaged. At the latter point, the socially efficient damage is achieved because the herders' marginal benefit is equal to the croppers' marginal damage cost (120 million FCFA/ha), so that the net social benefit is 48 million FCFA/ha. From the socially efficient damage, any one ton increase or decrease of crops' damage would induce the net social benefit to decline from 48 to 14.66 million FCFA/ha. Hence, to safeguard a socially efficient welfare, the government should encourage negotiated solutions between herders and croppers in such region where integrated crop-livestock farming systems are common.

Keywords: Coase theorem, cropper, externalities, herder, socially efficient, welfare
JEL: D62, H21, H23, Q18, Q51, O13

1 Introduction

After the 19th century Peul's conquest of North-Cameroon, the herds invaded the region and could freely pasture the land. However, with the development of agriculture in the region, the farmers are continuously clearing the numerous parcels of land available in the pastoral zones. In their territory, they destroy some fallow lands by suppressing the itineraries which were previously opened to the sheep-herds. With this reduction of pastures due to the multiplication of cultivated cropping areas, it becomes more and more difficult to prevent the incursion of herds in the famers' land (TCHOTSOUA and GONNÉ, 2009).

This difficulty is added to the fact that, the population of the region does not yet master the techniques which would enable them to associate together/simultaneously the agriculture and livestock/breeding practices. In this respect, HURAULT (1964) mentioned that, in the Banyo's lamida, "*agriculture and livestock remain two rigorously distinct activities which work in opposite directions*". Until now, the situation has not greatly changed as regards the land management problem between herders and croppers.

Currently, most farmers in this region face a conflict of land management between croppers producing maize on land and herders who breed cattle that needs land to graze on. Both individuals share adjoining land which is generally not enclosed in the region. The herders' breeding activity on the land unfortunately provokes the destruction of maize planted by the croppers under the same space.

This conflict problem between croppers and herders is exacerbated by the increasing population density and a continuous exploitation of land without fallow or application of insufficient fertilizers and organic matter quantities. Under those conditions, the production system in the region is not able to respond to the increasing food demand of the population of the main northern Cameroonian cities (Ngaoundéré, Garoua, Maroua, etc.) and even the national population which counts on the Adamawa production to sustain its food security.

As a matter of fact, the pastoral vocation attributed to the Adamawa region is materialized by the fact that it owns 28% of the national herd of cattle, 5% of sheep and 2.3% of goats (MINISTRY OF LIVESTOCK, 2012). The herd of cattle from this region contributes to 24% of the national production of meat, thereby making the Adamawa as the region which feeds the entire country and the surroundings CEMAC[1] African countries. Hence, there is an urgent need to solve the herders and croppers conflict in order to safeguard the food-self sufficiency of the population of CEMAC zone.

In economic terms, this conflict could be described by assuming that, the herder's damage is not counted as an externality imposed to the cropper i.e. the damage to the cropper does not currently appear into the utility function of the herder and vice-versa. However, according to the Coase theorem (1960), an internalization of the herder's externalities is important in order to get an efficient outcome which satisfies both parties (COASE, 1960). For instance, the herder can sacrifice part of its utility/satisfaction and put it at the benefit of the cropper. In this view, the main question that arises is to know what is the most efficient outcome by doing so? To which extent must the herder makes this sacrifice to the cropper? What is the calculated amount of welfare gain and loss by each party during the negotiation process? Thus, this paper attempts to answer those questions.

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[1] CEMAC refers to "Communauté Economique et Monétaire de l'Afrique Centrale" which is comprised of the six following countries: Cameroon, Congo, Gabon, Equatorial Guinea, RCA and Chad.

After the presentation of data collection and processing methods in the second section, the paper outlines the analytical framework (Coase theorem approach) in its third section. Afterwards, the results from field survey, the estimated utility/damage functions of each party (herder and cropper) and the results from Coase theorem are presented in the fourth section. Finally, the fifth section focuses on the discussions and conclusions arising from the paper.

2 Materials and Methods

2.1 Study Area and Data Collection

The field survey was carried out during the period from August 2012 to February 2013 in the Adamawa region of Cameroon, which was chosen because of the agro-pastoral vocation of its population. That region which extends over 62,000 km (total land area of 64,000 km^2) is located between the 6th and 8th degree of the northern latitude and between the 11th and 15th degree of the eastern longitude. It counts 799,000 inhabitants with a population density of 11.4 inhabitants/km^2 (compared to the 33.6 inhabitants/km^2 for the rest of the country). Apart from the major cash crops (such as coffee and cotton), the main food crops grown in the region are: maize, cassava, yam, potatoes, groundnut, plantain, tarot, etc. In total, the region counts a livestock's herd of 1,000,000 cattle; 1,501,000 goats; 200,000 sheeps; 1,000 pigs and 400,000 poultries (MINISTRY OF AGRICULTURE, 2012; MINISTRY OF LIVESTOCK AND ANIMAL HUSBANDRY, 2012).

The survey purposely selected two villages in each of the five departments of this region, which translated into a combined total of 10 villages throughout the whole study area. From their socio-demographic and economic characteristics, the selected villages were chosen for the survey because of the following reasons: (1) their great agro-pastoral nature provoking a big conflict of land management between herder and cropper, (2) the fact that these villages place the Adamawa at the first position of the regions which greatly contribute to meat and food production in the country and CEMAC zones. Because maize[2] is the main food crop of the region and country and its production is highly devastated by animals (one accounts harvest's loss of maize ranging from 6 to 82% depending on the location in the region), this crop was chosen for the survey. Likewise, the breeding of cattle being the mostly practised livestock activity which creates severe land management conflict in the region, it was chosen for this study.

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[2] Maize is ranked at the first position of food crops produced in the Adamawa region of Cameroon.

A number of 15 farmers (7 croppers and 8 herders) were randomly selected in each village which translated into a combined total of 150 farmers (70 croppers and 80 herders) throughout the whole study area. The selected croppers and herders were those farmers for which the main activities during the previous 10 years were the production of maize and the breeding of cattle, respectively.

With the aim to collect the data for further estimation of the quadratic function of Total Benefit (TB) to the herder and the linear function of Total Damage Cost (TC) to the cropper, the survey was conducted by using a prepared questionnaire and interview schedule. The primary collected data were the cross-sectional data of the cropping season 2012/2013. They were own estimations made by each farmer on his: cultivated land area (ha), number of cattle, production (t) and yield of maize (t/ha), damage rate of maize (%), revenue/benefit from maize production and/or from the breeding of cattle (FCFA[3]/ha), cost of production (FCFA/ha) and/or breeding (FCFA/cattle), damage cost (FCFA/ha), benefit/cost of remediation from damages (FCFA/ha), market price of maize (FCFA/t), market price of cattle (FCFA/head), etc.

2.2 Data Codification and Processing

After data collection, the data were codified and entered in computer with the help of EXCEL tabulation. For the data processing, the descriptive or statistical analysis (mean, standard deviation, minimum, maximum, etc) were done by using EXCEL for Windows. Furthermore, the SPSS software program (version 17.0) was used to estimate the coefficients of the quadratic Total Benefit (TB) function to the herder. The function of Total Damage Cost (TC) to the cropper was assumed to be linear because the marginal damages are held constant.

3 Data Analysis: Coase Theorem Approach

To achieve the study's objective, the Coase theorem approach is preferred because it is a typical illustration of the internalization of externalities by allocating the property rights either to the herders (polluters) or croppers (users) of the environment. This method is convenient for this paper because it would enable us to compute the socially efficient/optimal outcome and welfare gains and losses between croppers and herders through the functions of Marginal Benefit (MB) to the herder and Marginal Damage Cost (MC) to the cropper.

[3] FCFA (*Franc de la Communauté Financière Africaine*) is the local currency used in Cameroon. 1 Euro=655.957 FCFA; 1$US=500 FCFA.

3.1 Background and Application of the Coase Theorem to our Research Problem

The Coase theorem was published in 1960 by the economist and Nobel prize winner named Ronald Coase. It asserts that: "if property rights are well defined and transactions costs[4] are low, private parties can solve the problem of externalities on their own" (COASE, 1960). That means, in the presence of an externality, when property rights are involved, parties naturally gravitate towards the most efficient and mutually beneficial outcome. Or simply said, whatever the initial distribution of rights, the interested parties can always reach a bargain in which everyone is better off and the outcome is efficient.

This paper treats an example of land management problem between croppers cultivating maize on their land and herders who breed cattle that needs land to graze on. Both groups of farmers have adjoining land which is not enclosed and hence, the activity of one group (herders) provokes damage to the other group (croppers).

In the Coase theorem, the initial assignment of property rights does not matter for reaching an efficient solution. But for the benefits of the different groups involved, it greatly does – up to a level where the main issue is not about how to manage the situation given some established property rights but rather on how to distribute property rights (COASE, 1960). This study is undertaken in the Adamawa region of Cameroon which, from historical perspective, is a pastoral region with most laws in favour to the herders (rather than to the croppers), thus all our computations would be made by assuming that property rights are given to the herders.

3.2 Theoretical Computation of Welfare Gain and Loss by the Cropper and Herder

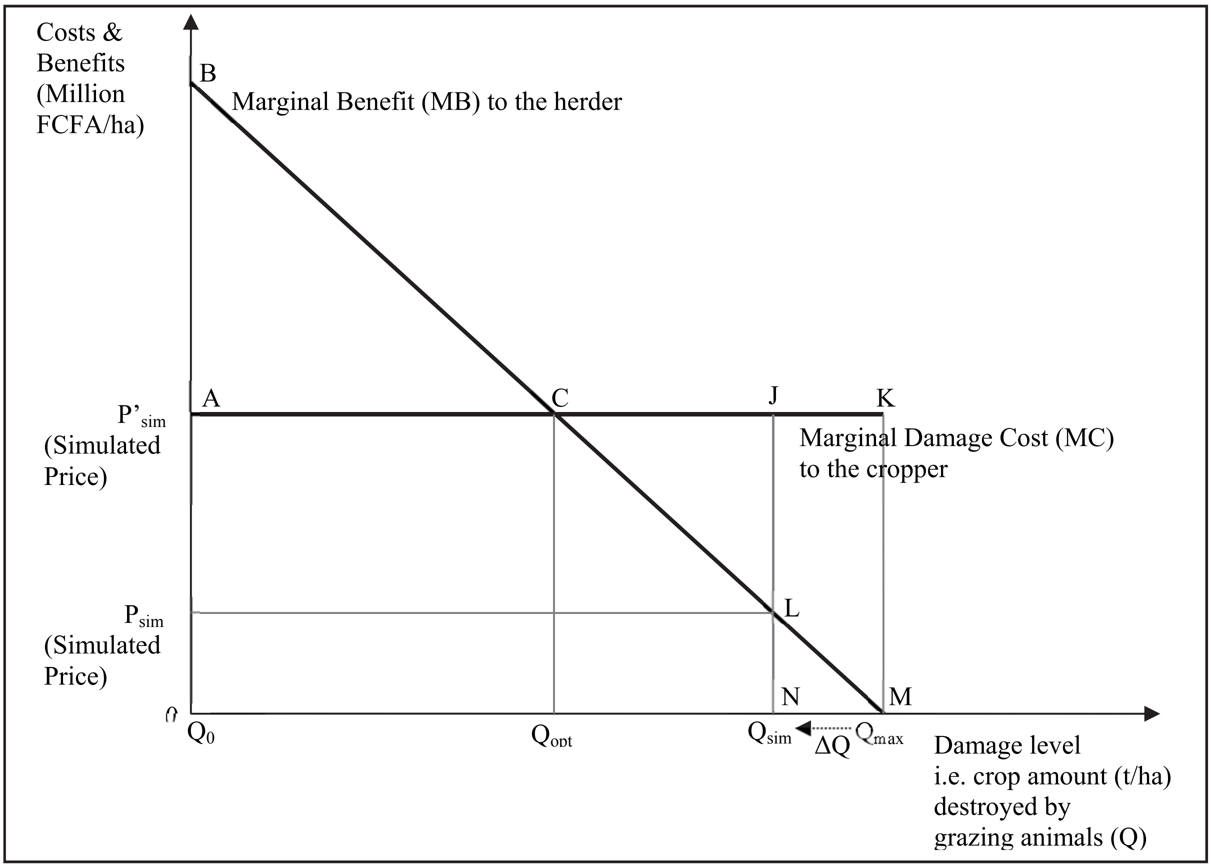
According to the Coase theorem (1960), when property rights are allocated to the herders (polluters), then the croppers (victims of pollution) will be motivated to bargain. If property rights are held by the croppers (victims), then the herders (polluters) will initiate negotiation (COASE, 1960).

Figure 1 illustrates the process in this study where property rights are allocated to the herders. The horizontal axis represents the damage level that is, the crop amount destroyed by grazing animals (Q). It is zero at Q_o and total at Q_{max}. The equilibrium is at Q_{opt}. The vertical axis shows the associated costs and/or benefits. MB depicts the Marginal Benefits (MB) to the herder (line BM). They are at their highest when damage is nil and at their lowest when there is total damage by herder. MC depicts the

[4] "Transaction costs" refer to negotiation costs such as time and communication/language translation costs.

marginal damage cost to the cropper (line AK). MC is constant, so does not change per damage level because the total damage cost to the cropper is a linear function (see Figure 1).

Figure 1. Coase theorem illustrating the herder's damage in cropper's land



Source: author's drawing from COASE (1960)

Looking at Figure 1, there are three main damage points on which we should emphasize. Firstly, the most efficient outcome which satisfies both parties (herders and croppers) is reached at Q_{opt} named as socially efficient level of crop damage. Zero damage is achieved at Q_0 whereas maximum damage occurs at point Q_{max}. Let's now assume that, we want to simulate the changes by moving from the maximum damage point Q_{max} to the simulated damage point Q_{sim} (by reducing the damage level by ΔQ), then the welfare gains and losses are the following computed areas of Figure 1:

- Triangle LMN=Reduction in herder's benefit
- Rectangle JKMN=Reduction in cropper's damage cost
- Trapezoid JKML=Societal gain

As depicted in Figure 1, suppose that the herder has the property rights. He would like to maximize his entire utility by operating at Q_{max} where the whole cropper's land (materialized by the total area inside the triangle 0MB0) is damaged. By simulating a situation when we move from Q_{max} to Q_{sim} (if we reduce damage level by ΔQ), then the herder's loses LMN in benefits whereas the cropper has damage cost reduced by JKMN. Hence, the societal gain is the difference between the reduction in cropper's damage cost *minus* the reduction in herder's benefit i.e. the rectangle's area JKMN *minus* triangle's area LMN which is equal to the trapezoid's area JKML (see Figure 1).

3.3 Mathematical Expressions of the Coase Theorem Applied to our Research

In order to illustrate the Coase theorem (see Figure 1), the estimations of the herder's Marginal Benefit (MB) and cropper's Marginal Damage Cost (MC) curves are necessary. The socially efficient level of crop damage/optimal damage point and the welfare gains and losses are subsequently computed from the two marginal curves (COASE, 1960). In this study, the herder's Marginal Benefit (MB) function is easily derived from the mathematical expression of its total quadratic function whereas the cropper's Marginal Cost (MC) function is assumed to be held constant (because damages to croppers is a linear function).

Generally, the mathematical expressions of the quadratic function of the Total Benefit (TB) to the herder and of the linear function of Total Damage Cost (TC) to the cropper are as follows (HEADY and DILLON, 1961; DOLL and ORAZEM, 1978; DEBERTIN, 1986):

– Total Benefit (TB) to the herder (quadratic function):
  $TB = a + b_1Q + b_2P + b_3Q^2 + b_4P^2 + b_5QP$

– Total Damage Cost (TC) to the cropper (linear function):
  $TC = a' + b'Q$

Where: **TB**: Total Benefit to the herder (in million FCFA/ha); **TC**: Total Damage Cost to the cropper (in million FCFA/ha); **Q**: Damage level i.e. crop amount destroyed by the grazing animals (in t/ha); **P**: Market price of maize crop (in million FCFA/t); **a', b'**: coefficients of the linear TC function; **a, b_1, b_2, b_3, b_4, b_5**: coefficients of the quadratic TB function, to be estimated in SPSS from field survey data.

Hence, the derived formulations of Marginal Benefits (MB) to the herder and Marginal Damage Costs (MC) to the cropper expressed in function of the amount of crops (Q) destroyed by the grazing animals are:

$$MB = \frac{\partial TB}{\partial Q} = b_1 + 2b_3Q + b_5P$$

$$MC = \frac{\partial TC}{\partial Q} = b'$$

Where: **MB**: Marginal Benefit to the herder (in million FCFA/ha); **MC**: Marginal Damage Cost to the cropper (in million FCFA/ha); **Q**: Damage level i.e. crop amount destroyed by the grazing animals (in t/ha); **P**: Market price of maize crop (in million FCFA/t).

Let's assume in Figure 1 that, we are moving from the maximum damage point Q_{max} to the simulated damage point Q_{sim} i.e. the herders decide to abandon the crop destruction of Q_{max} *minus* Q_{sim} tons per hectare of land. Then, we can compute the welfare distribution such as the: (1) reduction in herder's benefit ($Herder_{benefit's\ reduction}$), (2) reduction in cropper's damage cost ($Cropper_{damage's\ reduction}$), (3) societal gain ($Societal_{gain}$). The monetary values computed as surface areas are (see Figure 1):

$$Herder_{benefit's\ reduction} = \text{Triangle LMN} = \frac{(Q_{\max} - Q_{sim}) * P_{sim}}{2} = \frac{(\Delta Q) * P_{sim}}{2} \quad (1)$$

Where: P_{sim} is obtained by replacing the value of Q_{sim} in the mathematical expression of MB function; other notations are the same as earlier specified.

$$Cropper_{damage's\ reduction} = \text{Rectangle JKMN} = (Q_{\max} - Q_{sim}) * P'_{sim} = \Delta Q * P'_{sim} \quad (2)$$

Where: P'_{sim} is the same value as the MC; other notations are the same as earlier specified.

$$Societal_{gain} = \text{Trapezoid JKML} = \frac{(B + b) * H}{2} = \frac{[P'_{sim} + (P'_{sim} - P_{sim})] * (Q_{\max} - Q_{sim})}{2} \quad (3)$$

Where: B=Large Base=P'_{sim} which is the same value as the MC; b=Small Base=P'_{sim}-P_{sim}; H=Height=Q_{max}–Q_{sim}=ΔQ; other notations are the same as earlier specified.

Alternatively, the societal gain (as graphically shaped by trapezoid JKML) is also computed as:

$Societal_{gain}$ = $Cropper_{damage's\ reduction}$ - $Herder_{benefit's\ reduction}$
= Rectangle JKMN-Triangle LMN

4 Results

4.1 Field Survey Findings

4.1.1 Farm Characteristics of Croppers

Table 1 presents the field survey results of the production and estimated revenue and damage from selected maize farms of the Adamawa region during the cropping year

2012/2013. More precisely, the table shows the descriptive statistics (minimum, maximum, mean, standard deviation) computed from selected croppers (N=70) as regards to the cultivated land area, maize crop's yield, damage quantity, damage cost, gross and net revenues, etc.

Table 1. Production and estimated revenue and damage in selected maize farms, year 2012/2013 (N=70)

Variable	Minimum	Maximum	Mean	Standard Deviation
Cultivated land area (ha)	0.02	1.00	0.29	0.01
Yield of maize (t/ha)	0.33	5.01	2.51	0.20
Damage quantity of maize (t/ha)	0.22	2.74	1.62	0.09
Cost of damaged maize (thousand FCFA/ha)	26,400	328,800	194,400	10,800
Gross revenue of cropper (thousand FCFA/ha)	39,600	601,200	301,200	24,000
Net revenue of cropper (thousand FCFA/ha)	13,200	272,400	106,800	13,200

Notes:
(i) The cost of damaged maize is computed as: the damage quantity of maize (in t/ha) *multiplied by* the current market price of maize which is 120,000 FCFA/t.
(ii) The gross revenue of cropper is computed as: the maize crop yield (in t/ha) *multiplied by* the current market price of maize which is 120,000 FCFA/t.
(iii) The net revenue of cropper is: the gross revenue of cropper *minus* the cost of damaged maize.
Source: field survey results

From the table, the first highlight is that, the cultivated parcels of land are relatively of very small size in the study area. That is 0.29 ha on average from all selected farmers which is far below the 1.8 ha figure representing the average size of an agricultural exploitation in Cameroon. This could be attributed to the history and pastoral origin of the region where most parcels of land were firstly attributed to the herders at the detriment of croppers.

The results also indicate that, out of the average maize production of 2.51 tons cultivated in one hectare of land, about 1.62 tons are destroyed by the grazing cattle (see Table 1). In relative terms, this is equivalent to a yearly loss of 64.54% per hectare of produced maize. The low standard deviation of maize damage quantity (0.09 t/ha) explains that the rate of crop damage does not vary too much (is almost the same) from one cropper to another. The corresponding cost of damage maize is on average equal to 194,400 thousand FCFA/ha, which is important as it represents more than half of the average farmer's income in the study area (croppers have gross and net revenues averaging 301,200 and 106,800 thousand FCFA/ha per year, respectively) (see Table 1).

4.1.2 Cattle Size of Herders

Table 2 presents the cattle size and estimated revenue and damages from selected herders of the Adamawa region during the year 2012/2013. The cattle size is the number of cattle owned permanently by herders at any period of the year. On average, the herders from this region own permanently 35 grazing cattle per year (see Table 2). The large standard deviation of 23 indicates the wide variation of the cattle size from one herder to another. The herder with the highest number of animals has 202 cattle while the one with the smallest size owns 11 cattle (see Table 2).

Table 2. Cattle size and estimated revenue and damages from selected herders, year 2012/2013 (N=80)

Variable	Minimum	Maximum	Mean	Standard Deviation
Cattle size of herder (number per year)	11	202	35	23
Revenue of herder (FCFA/year)	2,200,000	40,400,000	7,000,000	4,600,000
Damage created to croppers (FCFA/year)	212,300	3,898,600	675,500	443,900

Notes:
(i) The revenue of the herder is computed as: the cattle size of herder *multiplied by* the current market price of one cattle which is 200,000 FCFA.
(ii) The damage created to croppers is computed as: the cattle size *multiplied by* the estimated damage of one cattle per hectare of land which is 19,300 FCFA.
(iii) The estimated damage of one cattle per hectare of land is taken from a previous publication by TCHOTSOUA and GONNÉ (2009).
Source: field survey results

The table also shows that, the revenues of herders vary according to the size of their herds. The mean revenue of herders is 7 million FCFA per year while the damage cost that their cattle provoke to croppers (by destroying maize) is 675,000 FCFA per year (see Table 2). The computed Pearson correlation coefficient r suggests that, the damage cost positively correlate with the herd size (r=0.804 significant at 1% level). In relative terms, the damage created to croppers represents about 9.64% of the herders' yearly revenue. Hence, the herder would not lose even if this damage cost is deducted from his revenue.

4.2 Estimated Quadratic Function of Total Benefit to the Herder and Assumed Linear Function of Total Damage Cost to the Cropper

Table 3 presents the results of the analysis when the herder's total benefit (TB) data are regressed (by using the *Ordinary Least Square* – OLS - method) against the five explanatory variables which are the: (1) quantity [Q] of maize destroyed by grazing animals (t/ha); (2) market price [P] of maize (FCFA/t); (3) squared-quantity [Q^2] of maize destroyed by grazing animals (t^2/ha); (4) squared-market price [P^2] of maize ($FCFA^2$/ha); (5) Crossed-destroyed quantity with market price [QP] of maize crop (t.FCFA/ha^2).

The common problem in studies of this type, multicollinearity, is examined through estimation of the Pearson correlation coefficient r between the five explanatory variables Q, P, Q^2, P^2, QP. In most cases, the results show weak insignificant correlation coefficients ($|r|<0.5$), indicating the absence of serious multicollinearity between explanatory variables.

In this regression function TB=f(Q, P, Q^2, P^2, QP), the value of coefficient of determination R^2 ranges within an acceptable value. The estimated R^2 value proves that, a percentage of 68.2% for the TB function is explained by the explanatory variables Q, P, Q^2, P^2, QP. Furthermore, the regression shows a F-value of the R^2 as significant (at 1% level) implying that, the estimated regression line fits the data very well (see Table 3).

For that regression, all the coefficients of the explanatory variables show the expected signs. We obtain a positive sign for the Q, P, P^2, QP variables and a negative sign for the Q^2 variable. That means, an additional quantity of maize crop destruction (Q) would induce a positive impact on the total benefit (TB) to the herder. Similarly, an increase in the market price (P) of the maize or in its squared-market price (P^2) would induce a positive impact on the total benefit (TB) to the herder. On the other hand, the negative coefficient for the Q^2 variable suggests that, the more the squared-quantity (Q^2) of maize destroyed by grazing animals, the less the total benefit (TB) to the herder. The interactive coefficient QP suggests that, an additional ton of maize crop destruction induces a larger herder's benefit for higher market price of maize (see Table 3).

As a matter of fact, when the price of maize increases in the market, then the cropper will tend to enlarge its land to produce large maize quantity in order to improve his profit; but unfortunately, part of this supplementary maize production will be destroyed by the herder's grazing animals (who become well fed) so as to increase the benefit to the herder.

Table 3. Estimated coefficients of the quadratic function of total benefit (TB) to the herder

Explanatory variables	**Coefficient**	**Level of significance (t-value)**
Constant (a)	0.0170	0.739
Quantity of maize destroyed by grazing animals Q (b_1)	50000***	4.711
Market price of maize P (b_2)	58.3330**	2.320
Squared-quantity of maize destroyed by grazing animals Q^2 (b_3)	-33333***	3.449
Squared-market price of maize P^2 (b_4)	0.0001	0.811
Crossed-destroyed quantity with market price of maize QP (b_5)	1.2500***	6.428
TOTAL	//	R^2=0.682 F-value=113.939***

Notes: ***: significant at 1% **: significant at 5 % *: significant at 10 %
Source: results from OLS regression in SPSS

In sum, from the estimated coefficients of Table 3, the quadratic total benefit (TB) function to the herder is mathematically formulated as (see Table 3):

$$TB = 0.0170 + 50000Q + 58.3330P - 33333Q^2 + 0.0001P^2 + 1.2500QP$$

For the TC (total damage cost to the croppers) function, we already mentioned in the footnotes of Table 1 that, the cost of damaged maize is computed as the damage quantity of maize (in t/ha) *multiplied by* the current market price of maize which is 120,000 FCFA/t. Thus, the function of total damage cost (TC) to the croppers is linear, as marginal damages are constant. Hence, the TC function is settled by assumption as:

$$TC = 120000\,Q$$

Hence, the derived mathematical expressions of the functions of the Marginal Benefit (MB) to the herder and the Marginal Damage Cost (MC) to the cropper are expressed as:

$$MB = \frac{\partial TB}{\partial Q} = 50000 - 66666Q + 1.2500P$$

$$MC = \frac{\partial TC}{\partial Q} = 120000$$

Where: **TB**: Total benefit to the herder (in million FCFA/ha); **TC**: Total damage cost to the cropper (in million FCFA/ha); **MB**: Marginal benefit to the herder (in million FCFA/ha); **MC**: Marginal damage cost to the cropper (in million FCFA/ha); **Q**: Damage level i.e. crop amount destroyed by the grazing animals (in t/ha); **P**: Market price of maize crop (in million FCFA/t).

The latter MC expression suggests that, every time that the herders give up (abandon) the destruction of one hectare of grazing land, then the damage of the croppers is reduced by an amount of 120,000 FCFA.

4.3 Results from the Coase Theorem Approach

4.3.1 Baseline Solution

In its baseline results, the paper suggests an optimal solution from the Coase theorem by using our field survey data and estimated costs and benefits functions. This solution indicates the socially efficient, maximum, and zero level of crop damage.

4.3.1.1 Socially Efficient Level of Crop Damage

The socially efficient level of crop damage is the point at which both parties (herder and cropper) are satisfied and can make acceptable agreement/tradeoffs. Since each individual would like to enjoy the highest utility, a compromise would be achieved at that point where the marginal benefit to the herder is *equal to* the marginal damage cost to the cropper.

To achieve this level and in light with the graphical representation of Figure 1, we must set the functions of herder's marginal benefit (MB) *as equal to* cropper's marginal cost (MC) and solve for Q in order to find this socially efficient level of crop damage. By doing so, and assuming the current market price of maize P as 120,000 FCFA/t, we have to solve the equation $50000 - 66666\,Q + 1.2500\,P = 120000$ which gives us a socially efficient level of crop damage of Q_{opt}=1.2 t/ha. This implies that, there is none complain between herders and croppers thus the two parties are satisfied when about 1.2 tons of crops are destroyed per hectare of land. This amount is also named as the optimal crop damage quantity i.e. the damage level for which both parties reach a compromise although the amount of benefits gained by each of them is not the same.

The corresponding marginal benefit to the herder at the socially efficient level is calculated by plugging the optimal damage level Q_{opt}=1.2 t/ha into the marginal benefit (MB) functions. By doing that, and assuming the current market price of maize P as 120,000 FCFA/t, we get:

$MB = 50000 - 66666\,Q + 1.2500\,P$ i.e.

$MB = 50000 - 66666\,(1.2) + 1.2500\,(120000) = 120{,}000$ i.e. 120 million FCFA/ha

Hence, at the socially efficient level of crop damage Q_{opt}, the computed marginal benefit to the herder (MB) gives the same result as the marginal damage costs (MC) already settled by assumption as MC=120 million FCFA/ha (see Table 4).

4.3.1.2 Maximum Level of Crop Damage

As earlier mentioned, the maximum level of crop damage Q_{max} is achieved at the point where the cropper bears the highest damage while the herder maximizes its utility/benefit. It is found by setting to zero the herder's marginal benefit function $MB = 50000 - 66666Q + 1.2500P = 0$. By solving that equation and assuming the current market price of maize P as 120,000 FCFA/t, we get a value of Q_{max}=3 t/ha which implies that, the amount of maize destruction could not exceed 3 tons per hectare of cultivated land.

We already said that the marginal damage cost to the cropper is set constant at 120,000 FCFA/t; so it is important to highlight that, even at the maximum level of crop damage, the MC to the cropper is still fixed at 120,000 FCFA/t whereas the MB to the herder is zero.

At this point Q_{max}, the herder's utility or Willingness-To-Pay is the total area under the marginal benefit (MB) curve lasting from zero (Q_0) to maximum damage quantity (Q_{max}) i.e. the surface area of triangle [BQ_0Q_{max}]=[(Base*Height)/2]=[(3*200)/2]= 300 million FCFA/ha (see Figure 2). Hence, when the maximum quantity of crops (Q_{max}=3 t/ha) is destroyed by grazing animals, then the herder enjoys its highest utility valued at 300 million FCFA/ha and which is earned at the detriment of the cropper who loses 120 million FCFA/ha (see Table 4).

4.3.1.3 Zero Level of Crop Damage

The zero level of crop damage is achieved when none quantity of maize is destroyed by grazing animals. We are here in a situation where the herder decides to stop his grazing activities or forbid to his cattle to divagate on the neighbouring croppers' land. In Figure 2, this is equivalent to setting the damage amount Q as equal to zero ($Q=Q_0=0$) so that the computed marginal benefit is:

$MB = 50000 - 66666(0) + 1.2500(120000) = 200{,}000$ i.e. 200 million FCFA/ha with the marginal cost held constant at MC=120 million FCFA/ha. Hence, when none quantity of maize is destroyed, the cropper's marginal cost is set at 120 million FCFA/ha whereas the herder's marginal benefit is valued at 200 million FCFA/ha (see Table 4).

To sum up the baseline solution, Table 4 shows the computed values of the herder's marginal benefit and the cropper's marginal cost computed at the socially efficient, maximum and zero level of crop damage.

Table 4. Herder's marginal benefit and cropper's marginal cost computed at the socially efficient, maximum and zero level of crop damage (baseline solution)

Variable	Damage level Q (in t/ha)	Marginal Benefit (MB) & Marginal Cost (MC) (in million FCFA/ha)
Socially efficient level of crop damage (Q_{opt})	1.2	MB=MC=120
Maximum level of crop damage (Q_{max})	3	MB=0 MC=120
Zero level crop of damage (Q_0)	0	MB=200 MC=120

Note: The Marginal Benefit (MB) and Marginal Cost (MC) are computed by replacing the crop damage level Q into the mathematical expression of MB=50000-66666Q+1.250P and MC=120000, respectively (by assuming a market price of maize P as 120,000 FCFA/t).

Source: Coase theorem results from field survey data and estimated functions

4.3.2 Results of Welfare Changes from Scenarios

The scenarios' results correspond to the simulated solution from the Coase theorem by assuming the situations where crop damage level is either increased or decreased. Hence, in this section, we will:

(1) assess the impact on net social benefit by varying the optimal crop damage level Q_{opt} in the positive and negative sense respectively in scenarios 1 (Sc.1) and 2 (Sc.2) such as: crop damage increase by one ton (Sc.1) and crop damage reduction by one ton (Sc.2).

(2) assess the impact on welfare distribution from one ton reduction of maximum crop damage (Sc.3).

In sum, in each scenario (Sc.1, Sc.2, Sc.3), we will assess the changes on the net social benefit or welfare gain and loss by each party (herder and cropper) and make policy recommendations based on those simulated results.

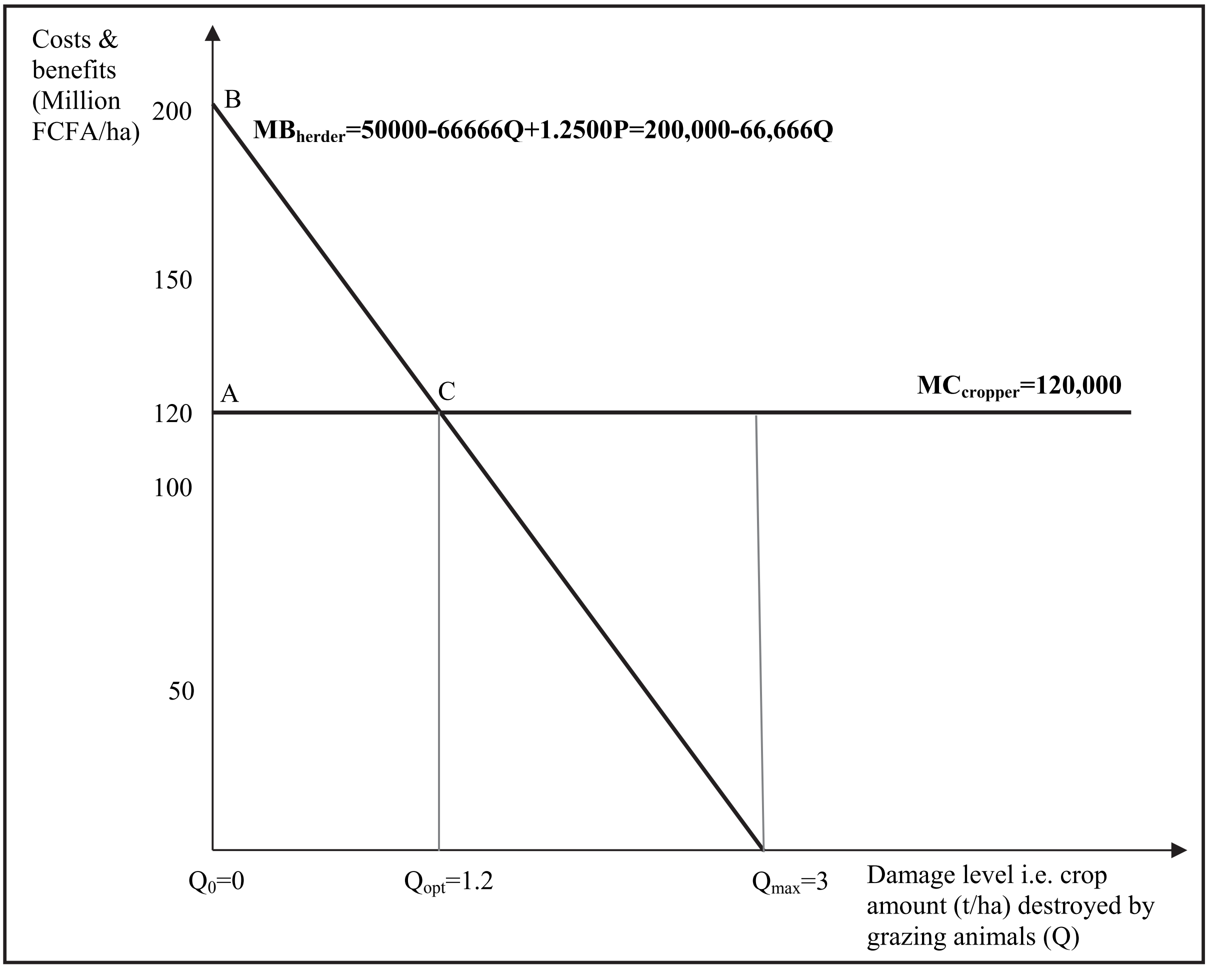
4.3.2.1 Impact of a Variation of Crop Damage on the Net Social Benefit

In this simulation, we will assume the baseline solution (i.e. net social benefit at the socially efficient level of crop damage) as our starting point. We will then assess the impact of variation of crop damage on the net social benefit when there is a:

– *Damage increase by one unit (Sc.1)*: From the efficient level Q_{opt}, we increase the crop damage by one ton (from 1.2 to 2.2 t/ha) (see Figure 2). The effect of this damage's increase on the net social benefit is measured in this scenario.

– *Damage reduction by one unit (Sc.2)*: From the efficient level Q_{opt}, we abate[5] the crop damage by one ton (from 1.2 to 0.2 t/ha) (see Figure 2). The effect of this damage's reduction on the net social benefit is measured in this scenario.

Figure 2. Illustration of the net social benefits at the socially efficient level of crop damage



Source: author's drawing from COASE (1960)

[5] Abatement=Reduction of crop damage level

Net Social Benefits at the Socially Efficient Level of Crop Damage

By definition, the net social benefits are the benefits *minus* costs. Graphically in Figure 2, the net social benefits are the area under the marginal benefit curve [Q_0ABCQ_{opt}] *minus* the area under the marginal cost curve [Q_0ACQ_{opt}]. Hence, the net social benefits are depicted as the area [ABC] between the curves of marginal benefit to the herder (MB_{herder}) and the marginal damage cost to the cropper ($MC_{cropper}$) when the damage quantity lasts from zero (Q_0) until the socially efficient level (Q_{opt}). That area [ABC] has a triangular shape implying that, its surface area is computed as: $[(Base * Height)/2]$ which in numerical terms is equal to $[(200-120)(1.2)/2]=48$ million FCFA/ha (see Figure 2).

Scenario 1: Impact of One Ton Increase of Crop Damage on Net Social Benefit

From the socially efficient level Q_{opt}, if there is one more ton of crop damage per hectare (from 1.2 to 2.2 t/ha), then the net social benefit is computed as the surface areas of triangle [ABC] *minus* triangle [CHI] (see Figure 3) which in numerical terms is equal to: [48-0.5(120-53.33)(2.2-1.2)]=48-33.335=14.665 million FCFA (see Table 5).

Table 5. Net social benefit computation when the crop damage is increased (Sc.1) or decreased (Sc.2) by one ton from the socially efficient level (Q_{opt})

Scenario (Sc.)	**Sc.1: One ton increase in crop damage level Q (from 1.2 to 2.2 t/ha)**	**Sc.2: One ton decrease in crop damage level Q (from 1.2 to 0.2 t/ha)**
Crop damage Q level	Q=1.2+1=2.2 t/ha	Q=1.2-1=0.2 t/ha
Marginal Benefit ($MB = 200{,}000 - 66{,}666Q$)	$MB = 200{,}000 - 66{,}666 * 2.2$ =53334.8	$MB = 200{,}000 - 66{,}666 * 0.2$ =186666.8
Marginal Cost ($MC = 120{,}000$)	MC=120,000	MC=120,000
Net Social Benefit	= Triangle ABC-Triangle CHI = 48-33.335 = 14.665 million FCFA/ha	=Triangle BEF+Rectangle DEFA =1.333+13.334 =14.667 million FCFA/ha

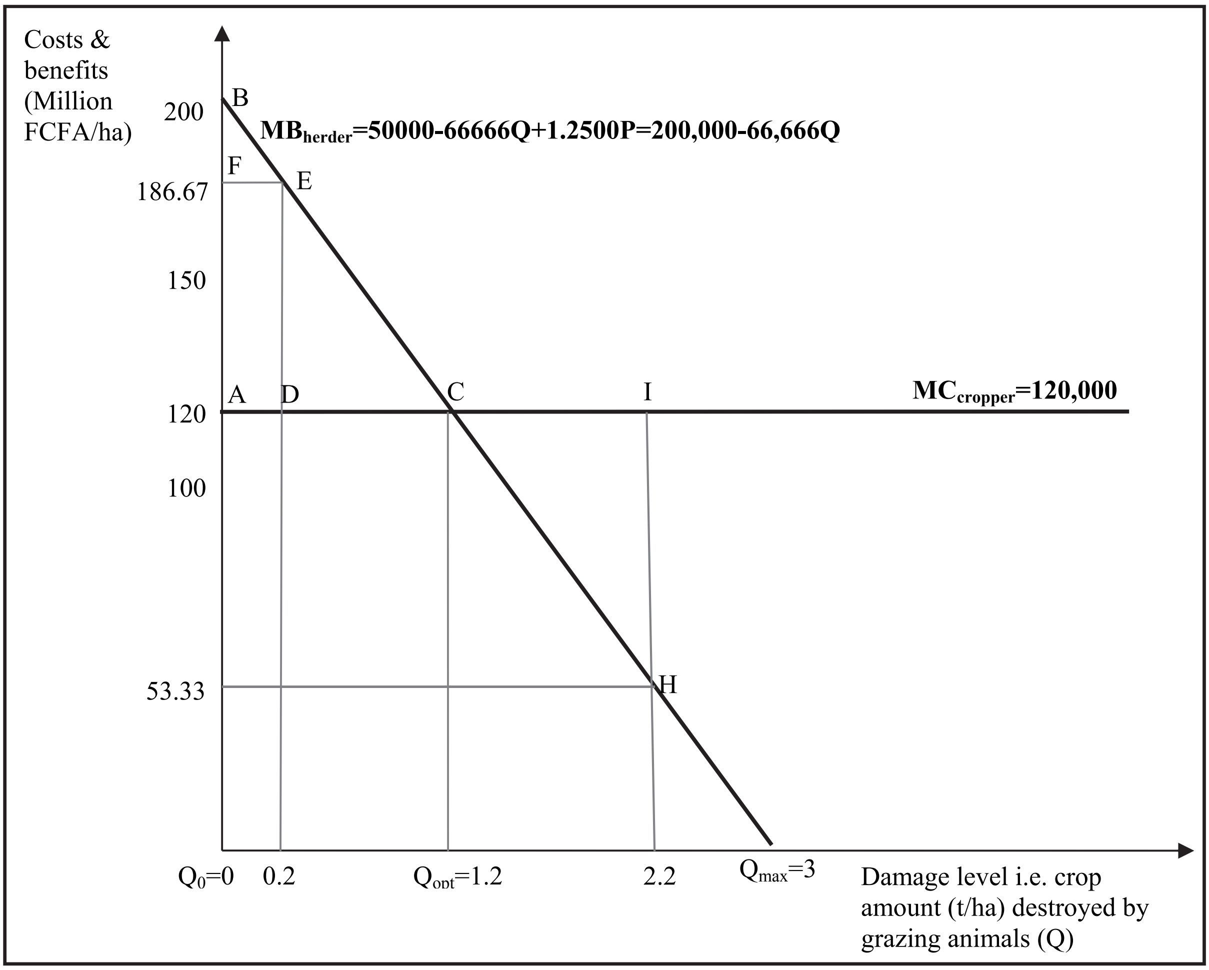
Notes:
(i) In Sc.1, the surface area of triangle CHI is equal to: [(120-53.33)(2.2-1.2)]/2=33.335 million FCFA. Hence, the net social benefit represented by the triangle's areas [ABC-CHI], is valued as 48-33.335 =14.665 million FCFA/ha (see Figure 3).
(ii) In Sc.2, the net social benefit is equal to the area [ABED], which is: Triangle BEF plus Rectangle DEFA =[0.5(200-186.67)(0.2)]+[(186.67-120)(0.2)]=1.333+13.34=14.673 million FCFA/ha. Alternatively, the area [ABED] has a trapezoid shape with a surface area of: [(80+66.67)*0.2/2]=14.667 million FCFA/ha (see Figure 3).

Source: simulated solution from Coase theorem approach

Scenario 2: Impact of One Ton Reduction of Crop Damage on Net Social Benefit

From the socially efficient level Q_{opt}, if you abate one ton of crop damage per hectare (from 1.2 to 0.2 t/ha), then the net social benefit is represented by the area [ABED] (see Figure 3), which is decomposed into Triangle BEF *plus* Rectangle DEFA= [0.5(200-186.67)(0.2)]+[(186.67-120)(0.2)]=1.333+13.334=14.667 million FCFA/ha. Alternatively, the area [ABED] has a trapezoid shape with a surface area of: [(80+66.67)*0.2/2]=14.667 million FCFA/ha (see Table 5).

Figure 3. Net social benefit's representation when the crop damage is increased (Sc.1) or decreased (Sc.2) by one ton from the socially efficient level (Q_{opt})



Source: author's drawing from COASE (1960)

In conclusion, the result is the same in any of the two cases when the crop damage is either increased (Sc.1) or decreased (Sc.2) by one ton per hectare of land. More precisely, from the socially efficient level Q_{opt}, any one ton increase or decrease of crop damage would induce the net social benefit to decline from 48 to 14.66 million FCFA/ha (see Table 5).

4.3.2.2 Impact on Welfare Distribution from One Ton Reduction of Maximum Crop Damage

Apart from Sc.1 and Sc.2, the study attempts in a different scenario (Sc.3) to assess the impact on welfare distribution when the maximum crop damage is reduced by one ton i.e. from Q_{max}=3 to Q_{sim}=2 t/ha. In order to measure such effect, we start from the assumption that the herder has the property rights in this study, and then compute and analyse: (1) the reduction in herder's benefit, (2) the reduction in cropper's damage cost, and (3) the societal gain [see Figure 1 and Table 6].

Reduction in Herder's Benefit

By replacing symbols with their values in Figure 1, the reduction in herder's benefit ($Herder_{benefit's\ reduction}$), as earlier formulated in Equation (1) is computed as follows:

$$Herder_{benefit's\ reduction} = \text{Triangle LMN} = \frac{(Q_{\max} - Q_{sim}) * P_{sim}}{2} = \frac{(\Delta Q) * P_{sim}}{2} = \frac{(1) * 66{,}668}{2} = 33{,}334 \tag{4}$$

Where: P_{sim} is obtained by replacing the value of Q_{sim} in the mathematical expression of MB function; other notations are the same as earlier specified.

Where:
$\Delta Q = Q_{max} - Q_{sim} = 3-2 = 1$; $P_{sim} = MB_{sim} = 200{,}000 - 66{,}666Q = 200{,}000 - 66{,}666(2) = 66{,}668$

The computed result of $Herder_{benefit's\ reduction}$ suggests that, because it is the herder which holds the property rights, he loses a benefit of an amount of 33,334 i.e. approximately 33 million FCFA/ha if he decides to lower the crop damage level by one ton (see Table 6).

Reduction in Cropper's Damage Cost

By replacing symbols with their values in Figure 1, the reduction in cropper's damage cost ($Cropper_{damage's\ reduction}$), as earlier formulated in Equation (2) is computed as follows:

$$Cropper_{damage's\ reduction} = \text{Rectangle JKMN} = (Q_{\max} - Q_{sim}) * P'_{sim} = \Delta Q * P'_{sim} = (1)*(120{,}000) = 120{,}000 \tag{5}$$

Where: $\Delta Q = Q_{max} - Q_{sim} = 3-2 = 1$; $P'_{sim} = MC = 120{,}000$

The computed result of $Cropper_{damage's\ reduction}$ suggests that, the cropper has damage costs reduced by an amount of 120 million FCFA/ha if the herder lowers the crop damage level by one ton less from maximum (see Table 6).

Societal Gain

By replacing symbols with their values in Figure 1, the societal gain ($Societal_{gain}$), as earlier formulated in Equation (3) is computed as follows:

$$Societal_{gain} = \text{Trapezoid JKML} = \frac{(B+b)*H}{2} = \frac{\left[P'_{sim} + (P'_{sim} - P_{sim})\right]*(Q_{\max} - Q_{sim})}{2} \quad (6)$$

$$= \frac{\left[120{,}000 + (120{,}000 - 66{,}668)\right]*(3-2)}{2}$$

$$= \frac{\left[120{,}000 + (53{,}332)\right]*(3-2)}{2} = \frac{\left[173{,}332\right]*(1)}{2} = 86{,}666$$

Where: $P_{sim}=MB_{sim}$=200,000-66,666Q=200,000-66,666(2)=66,668;
Large Base B=P'sim=120,000; Small Base b=P'_{sim}-P_{sim}=120,000-66,668=53,332;
H=Height=Q_{max}–Q_{sim}=3-2=1

Alternatively, the societal gain could also be computed by subtracting the reduction in cropper's damage cost ($Cropper_{damage's\ reduction}$) to the reduction in herder's benefit ($Herder_{benefit's\ reduction}$) i.e. Rectangle's area JKMN *minus* Triangle's area LMN= 120,000-33,334=86,666 which is exactly the same result computed directly from the trapezoid's area. The computed result of $Societal_{gain}$ suggests that, the gain of the society (public welfare) is 86,666 i.e. approximately 87 million FCFA/ha if the herder decides to abate the crop damage by one ton less from the maximum level (see Table 6).

Table 6. Welfare distribution resulting from a reduction of the maximum crop damage (Sc.3) by one ton (from 3 to 2 t/ha)

Variable	**Welfare gain or loss (in million FCFA/ha)**
Reduction in herder's benefit	33
Reduction in cropper's damage cost	120
Societal gain	87

Notes:
(i) One ton reduction in crop damage is equivalent to one-third abatement i.e. [(3-2)*100/3]%= 33.33%.
(ii) The societal gain is: the reduction in cropper's damage cost *minus* the reduction in herder's benefit.
Source: simulated solution from Coase theorem approach

A summary of all results from this scenario is shown in Table 6. In monetary values, the computed figures suggest that, a one-third (33.33%) abatement in crop damage level (from 3 to 2 t/ha) would disturb the welfare distribution so as to induce a 33 million FCFA/ha of reduction in herder's benefit, a 120 million FCFA/ha of reduction in cropper's damage cost, and a societal gain of 87 million FCFA/ha (see Table 6).

5 Discussions and Conclusions

5.1 Herder and Cropper Should Operate at the Socially Efficient Level of Crop Damage

This paper applies the Coase theorem by assuming that the property rights are given to the herder. The results show that, when none crop amount is damaged, the herder loses the most whereas the cropper earns his highest benefit (see Table 4 and Figure 2). However, the herder provokes the maximum damage to the cropper when 3 tons of crops are destroyed per hectare of land. At this damage level, the totality i.e. 100% of crops in the land is used as pasture by the grazing animals. This latter point is inefficient because only the herder enjoys his highest utility while the cropper records his highest loss (see Table 4 and Figure 2). However, the damage of the cropper could be reduced if the herder sacrifices part of his utility (by earning a smaller benefit than before) and grant it to the cropper.

The paper shows however that both parties (herders and croppers) are satisfied when they operate at the socially efficient level of crop damage i.e. the optimal point Q_{opt}=1.2 t/ha where the curves of herder's marginal benefit and cropper's marginal damage cost intersect (see Figure 2). At this point, the crop damage rate is computed as: [(1.2*100)/3]=40%. This is the acceptable proportion of maize that the grazing cattle can destroy in the croppers' land. Any crop destruction beyond this proportion is socially inefficient. The field survey results suggest that, from an average maize production of 2.51 t/ha, about 64.54% of it is actually damaged by cattle (see Table 1). However, the Coase theorem approach enables both parties to reach a compromise at a more reduced damage rate i.e. 40% of maize would be destroyed by the grazing cattle, so that the croppers remain with 60% of his harvested crop (about 1.51 t/ha). This is part of his sacrifice in order to reach a socially efficient outcome.

Hence, to safeguard a socially efficient welfare, the government should encourage negotiated solutions between herders and croppers in such region where integrated crop-livestock farming systems are common. This is possible through the creation of cooperatives grouping all farmers (herders and croppers), so that the two parties could better discuss on topics which preserve the interests of every group.

5.2 Integrated Crop-Livestock Farming Systems are Necessary at Socially Efficient Level

Our computed results from the Coase theorem indicate that (Table 4), both the croppers and herders are satisfied if the crop damage rate stands at 40% i.e. the crop damage rate should lie at the socially efficient level of 1.2 tons for every one hectare of cultivated land. Adamawa being a region where both agriculture and livestock enormously contribute to the country's or CEMAC zone's food security, the activities of the two groups of farmers (herders and croppers) have to be taken into consideration.

From our previous results (Table 4), operating at maximum or zero crop damage levels would favour only one party (either herder or cropper) at a time. We already said that, both parties reach a compromise at the socially efficient level of crop damage (see Table 4 and Figure 2). From the socially efficient level of Q_{opt}=1.2t/ha, any one ton increase or decrease of crop damage would induce the net social benefit to decline from 48 to 14.66 million FCFA/ha (see Table 5). Thus, any shift from this level would be detrimental to the social welfare. Hence, a socially efficient outcome which integrates both farming and livestock activities is necessary.

In order to reach that socially efficient level, we recommend two systems of crop-livestock integration to be put into practice in that region. The first system referred to as "closely integrated" is the situation in which crop and livestock production is combined under the same management (ELZAKI et al., 2007). With such a system, neighbouring farms with the cropper on the one side and the herder on the other side could share the same parcel of land by using a fence which would separate the herders' farm to the croppers' plantations. In this way, only a small proportion of animals which would have exceptionally crossed the fence could destroy the cropper's land. The second system termed as "segregated integrated" is a situation in which the herders' and croppers' products are separated but are involved in an exchange contract based on the exchange of manure for crop residues and grazing with transhumance herders (OMOLEHIN and NUPPENAU, 2007).

Hence, the government authorities could lower the crop damages by implementing policies which are related to any of the two types of farming systems. For instance, a ranching system which awards credit to herders for the fence construction should be launched. Through that system, any herder could apply for credit from the public banking institutions in order to: (1) construct farms enclosed with fence, (2) purchase the cattle to be bred within an enclosed fence, and (3) benefit from good quality of pasture to feed his cattle (TCHOTSOUA and GONNÉ, 2009).

Furthermore, the fodder production in every farm structure should be advertised. Since the pasture is very scarce in the region, and expensive in the market, the herders are obliged to let their cattle free to divagate into the farmers' land. So, if the initiative of fodder production by croppers in order to sell it to herders is popularized, then the animals would no more divagate in neighbouring lands in the search of pasture and hence the crops would grow without any danger. Another alternative would be to train the herders so that they could produce their own fodder (just in case they do not want to let the croppers to produce it and sell to them).

The other way to solve such a problem of land management could be the implementation of a rotation system where the herders agree with croppers to alternate or rotate their activities i.e. the croppers leave their land in fallow during the first cropping season in order to allow the herders to graze their cattle in that land. The second year would be the turn of the croppers to fully implement their activities in the land while the herders put their cattle in an enclosed space and on so on for subsequent years. Further solutions could be to implement a system of annual permit to herders in function of the availability of grazing land in the region.

5.3 Negotiated Solution between Herders and Croppers is Environmentally Beneficial

Apart from maize crop destruction, an intensive grazing by cattle also has detrimental environmental effects on grassland of the Adamawa region. From our computed results (Table 4), the outcome which allows the herders to operate at the maximum level of crop damage (3 t/ha) is environmentally unsustainable because it engenders severe overgrazing. According to TCHOTSOUA and GONNÉ (2009), the overgrazing under natural grasses leads to erosion rates of about 10 to 50t/ha/year depending on the locality of the Adamawa region. The same study reveals that, the disappearance of a few hundred of several species found during the 19^{th} century in the region is attributed to the intensive grazing of land by cattle (TCHOTSOUA and GONNÉ, 2009). However, from our computed results, the most sustainable environmental solution (with none grazing effect) is found at the zero level of crop damage (Table 4); but this outcome does not satisfy the herders. We already demonstrated that, a negotiated solution between herders and croppers is achieved at an acceptable grazing rate when only 1.2 tons of crops are damaged per hectare of cultivated land (Table 4). Our results also show that, from that socially efficient level, any one ton increase or decrease of crops' damage would induce the net social benefit to decline from 48 to 14.66 million FCFA/ha (Table 5). Hence, for the benefit of the whole society and to safeguard the interest of present and future human's generations, it would be environmentally sustainable to operate at that socially efficient level because it could help to lower erosion rate and protect the grassland while conserving the biodiversity of species of the Adamawa region.

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