Global Academic Journal of Economics and Business

Available online at https://www.gajrc.com
DOI: 10.36348/gajeb.2024.v06i01.003

OPEN ACCESS

ISSN: 2706-9001 (P)
ISSN: 2707-2584 (O)

Original Research Article

Analysis of the Economic Impact of Research and Agricultural Extension of Sesame in Burkina Faso

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Article History
Received: 17.12.2023
Accepted: 22.01.2024
Published: 16.02.2024

Abstract: This study aims to assess the economic impact of research and extension as for improved sesame varieties in Burkina Faso. Indeed, the effectiveness of the use of financial resources allocated to research and extension is a concern for donors and governments of different countries. The economic surplus model was used as an analytical tool for this study. Thus, data were collected from research, extension and statistical data production structures. This method evaluates the impacts in terms of shift of the supply curves. The results of the model show that it is benefitting to invest in cowpea research. In fact, in this study, the internal return rate is about 69% for the period ranging from 2006 to 2018, with a net added value nearly 372 billion FCFA. Such high rates could only be achieved through the relevance of the research results and their dissemination / adoption. Therefore, for a development of the sesame sector and an improvement of producers 'income, the investment in the research is essential.

Keywords: Impact, sesame, economic surplus, extension, research, Burkina Faso.

INTRODUCTION

Increasing agricultural production in Sub-Saharan Africa has become a political objective aimed at ensuring the food security of populations and one of the main strategies adopted in this region consists of strengthening agricultural production systems through the use of seeds improved (Miko, 2012; Clavèle, 2016). Indeed, improved seeds help increase productivity and achieve food security in rural communities. According to Masa (2013), improved seed contributes nearly 40% to yields in good production conditions compared to traditional seeds. Improved seeds therefore constitute an important component in agricultural production. However, their use still remains low in Burkina Faso; in 2021, only 15.6% of rainfed areas had used improved seeds (Marah/Dgess, 2022) and these areas sown with improved varieties are also very disparate. For cotton, the total area sown with improved seeds is 93.7%; soya and corn follow with 35.5% and 27.5%, millet at 5.9% and white sorghum with 5.6%; 17.4% of rice areas are also improved varieties, as are 16% of sesame areas (Marah/Dgess, 2022). To reverse this trend, the country has undertaken for several years development policies for the agricultural and rural sector which have resulted in certain programs such as the Strategic Framework for the Fight against Poverty (CSLP), the Accelerated Growth and Sustainable Development Strategy (SCADD) and the PNDES. These policies, for the most part, have made the agricultural sector a lever for growth in which cash crops actively participate. Among cash crops, sesame increasingly stands out as a diversification cash crop compared to cotton, a source of secure income for producers. Indeed, the sesame sector has experienced remarkable growth in recent years in Burkina Faso. This growth was favored by a global context characterized by strong demand for sesame coupled with the fall in the price of cotton. All of which has had a knock-on effect on sesame production, which has increased considerably in recent years, from 22,887 tonnes in 2006 to 384,614 tonnes in 2020 (Marah/Dgess, 2022). Exports also experienced a significant increase over the same period, making sesame the third product after shea and cashew nuts in terms of exports of plant production in Burkina Faso.

With a view to improving productivity and meeting the needs of ever-growing populations, different varieties have been created by research and popularized. These varieties, with high agronomic potential, lead to considerable increases in yields. The food crisis of 2008 and the economic crises that followed served as a reminder that increasing agricultural production to meet ever-increasing food demand requires the use of technologies with high productivity potential. It has therefore aroused great interest in new technologies developed by agricultural research. Governments have financed and made available to producers inputs including improved seeds, with the aim of increasing the food supply.

However, the creation of improved sesame varieties involves very significant costs so that policy makers and partners are asking questions about the profitability of research activities in general and those on sesame in particular. The socio-economic impact of research measured in terms of rate of return on public investments is neither obvious nor demonstrated despite all the funds that are injected. The question of the economic profitability of public investments made in research programs, the popularization of technologies and innovations created or developed by research constitutes a concern for political decision-makers, donors and researchers in Burkina Faso. Moreover, researchers and research managers are often challenged by the question of the impact of agricultural research. The economic value of a public investment is not obvious. It is particularly difficult to observe the impact of agricultural research given that the benefits are spread over several years and are distributed among several million producers and consumers. Economic studies are necessary to measure these benefits and compare them with the costs of research (Masters and Ly, 2003). The economic evaluation of agricultural research makes it possible to obtain feedback to assess the practical interest of its work (Ahmed *et al.*, 1994).

Agricultural research provides new knowledge and new materials such as seeds, fertilizers and equipment. The overall objective of agricultural research on sesame in Burkina Faso is to contribute to increasing production with a view to achieving food self-sufficiency through the modernization and intensification of its cultivation. Research on sesame has been carried out since 1955 by the Research Institute for Oils and Oilseeds (IRHO) in Burkina Faso, within the framework of the convention on scientific cooperation between our country and France (Djigma, 1984). On the varietal level, researchers carried out introductions of exotic varieties, prospecting for local varieties, and creations through hybridization and selection. It first identified high-yielding varieties adapted to the different agro-ecological conditions of the country and subsequently set about developing varieties. The importance of sesame in the trade balance of Burkina Faso justified research work on this speculation in order to increase its productivity and production (Djigma, 1984). In 1982, the yield of sesame was around 347kg/ha. It is therefore to shed light on this subject for political decision-makers and donors that we propose to carry out an ex post evaluation of the profitability of investments made for sesame research in Burkina Faso.

The general objective of this research is to evaluate the economic impact of research and popularization of improved sesame varieties in Burkina Faso. More specifically, for us it is about: (1) Determining the added value created by the adoption of technologies developed by sesame research; (2) Determine the rate of return on investments in agricultural research on sesame in Burkina Faso.

The rest of the paper is structured around the literature review, the materials and methods and the presentation of the results and their discussion. The conclusion summarizes the main results and outlines the policy implications.

1. LITERATURE REVIEW

The literature is abundant on impact studies. Indeed, impacts are defined as “long-term effects, positive and negative, primary and secondary, induced by a development action, directly or not, intentionally or not” (OECD, 2022). An impact analysis is not just a comparison of a situation without research to an alternative with research. External conditions are constantly changing and introduce bias into such an analysis. In order to take these biases into account and only keep the desired actions, different theories are proposed by researchers. Evaluating the economic impact of research consists of comparing a situation without research to that with agricultural research. According to Masters and Sanders (1996), the methods for economic estimation of the impact of agricultural research belong to three main groups: econometric methods, mathematical programming and the economic surplus method. For them, econometric methods estimate the marginal productivity of research over a long period. They use a production function, a cost function or a total factor productivity analysis to estimate a changé in productivity due to research investments (Maredia *et al*., 2000). Since it is very difficult to separate the impact of research from other factors such as input prices, rainfall, farmer training, these study methods are specifically undertaken only if there is a lot of data (Masters and Ly, 2003). Programming methods attempt to identify one or more alternative technologies or options in a set of research activities. They seek to maximize an objective, for example the operator's profit under the constraint of availability of factors (land, capital). This is done by specifying a mathematical model that quantifies the objective and constraints, for example, to maximize something while taking other things into account. These are methods that remain more data intensive (Masters and Ly, 2003).

In the literature, the economic surplus method measures aggregate social benefits. With this method, it is possible to estimate the rate of return on investments by calculating the variation in consumer surplus and producer surplus through technological change; it is used with research costs to calculate net present value (NPV), internal rate of return (IRR) or benefit/cost ratio (BCR) (Maredia *et al*., 2000). This model has often been used by several authors such as Ahmed *et al*., (1994), Souleymane *et al*., (2018) and Pierre (1976), to determine the profitability of investments devoted to research and the popularization of new technologies. Furthermore, this method can produce useful and effective information to show the benefits produced by agricultural research. Economic surplus is made up of two elements: consumer surplus and producer surplus. Consumer surplus is the difference between the price the consumer would be willing to pay for each additional unit up to the total quantity purchased and the price he actually pays for each unit of a good on the market. By analogy, producer surplus is the difference between the price at which he is willing to sell each additional unit of the product up to the total quantity sold and the price at which he sells his product in the market. The sum of consumer and producer surplus constitutes economic surplus. It can be defined as the amount of money that the consumer would have paid for each unit consumed minus the amount of money that the producer would have sold for each unit produced before reaching the equilibrium point between price and quantity on the market (Masters and Sanders, 1996). Any change in economic surplus is a measure of the social benefits derived from the research. The surplus method therefore essentially expresses the distinction and interdependence between the creation of value on the one hand and its distribution between the various social partners on the other. It is thus led to interpret net volume variations as the measure of wealth creation due to internal performance and price variations as the means of distributing this wealth between social partners.

According to Marah/Dgess (2022), sesame is traditionally cultivated in the different regions of Burkina Faso, ranging from the driest to the wettest areas and from the poorest to the richest soils. It is an easy crop to maintain, therefore low production costs. The sown areas increased from 143,662 ha in 2010 to 644,890 ha in 2020 and production from 90,651 to 384,614 tonnes during the same period with more or less significant fluctuations from one year to the next (Marah/Dgess, 2022). According to Apex (2022), five (05) regions stand out with higher average production volumes over the last ten years. These are the regions of Boucle du Mouhoun (30%), East (20%), Hauts-Bassins (10%), Cascades (9%) and Centre-West (7%) (Apex, 2022). The increase in cultivated areas and the increasingly strong international demand for Burkinabè sesame partly explain this upward trend in areas and production. National production is evolving unevenly, although with an upward trend during the 2010-2020 period. And, since the start of the 2010 decade, the sesame sector has experienced remarkable growth in our country. This growth was favored by a global context characterized by strong demand for sesame coupled with the fall in the price of cotton. Anything that had a knock-on effect on sesame production. Production has increased considerably in recent years, from 22,887 tonnes in 2006 to 384,614 tonnes in 2012 (Marah/Dgess, 2022). Exports also experienced a significant increase over the same period, making sesame the third largest export product in agricultural crop production in Burkina Faso. Sesame export revenues are estimated at more than 350 billion CFA Francs from 2010 to 2016, making the country fourth in the world among sesame exporting countries behind Ethiopia, India and Sudan. In 2019, Burkina Faso is the 8th world producer of sesame with 5.3% of world production and the 4th African producer after Sudan, Tanzania and Nigeria (faostat, 2021). Burkinabè sesame is mainly exported to Singapore which absorbs 55% of total exports, followed by Japan 12.6%, Togo 12%, Ghana 10.6%, China 3.4%, United Arab Emirates 3 .1%, Israel 1.3%, France (0.6%) and Turkey (0.5%) (Apex, 2022). Burkina Faso's sesame exports represent on average 1.9% of world exports in 2020. Burkina Faso is the 13th world exporter of sesame in 2020 with 60,770 tonnes of sesame for a value of $64.2 million (Apex, 2022).

From an empirical point of view, several research programs have been subject to impact evaluation in order to provide feedback to planners and investors. Zagbaï *et al.*, in 2008 in their study evaluating the economic impact of cotton without gossypol in Côte d'Ivoire show that the average yield gain initially sought did not occur. Indeed, the estimated net present value (NPV) was negative. Which means that producers were losing money by adopting this variety. Following the introduction of this variety, national production declined, even leading to a drop in production. This would explain the suspension of the promotion program for this variety in Ivory Coast.

After investing in seven African countries, USAID found itself in a climate of disappointment and even managed to reduce its allocations for agricultural research in Africa. Indeed, experts from this organization believed that investment in agricultural research had not proven profitable. To understand more, it commissioned impact studies whose main objective was to provide empirical evidence of the performance of their investments in agricultural research programs in Africa. In general, the rates of return obtained for these studies are acceptable, as long as they are higher than a typical target rate such as 10-12% (savings rate in commercial banks). And these studies concluded that increased investment in agricultural research was justified (Crawford, 1993). In Senegal, the basic study which served as a reference for evaluation studies of research programs was carried out by Sanders *et al.*, (1998) and focused from an ex-post perspective on the impact of research and extension on the cotton sector in Senegal. With 38% IRR, this level of profitability represents a reasonable performance for a public sector investment (Fao, 1998).

Still in Senegal, to justify that agricultural research pays off, Fall (2005) conducted a study to evaluate the economic impact of research and extension of rice in the Senegal River Valley. This analysis made it possible to quantify the contribution of research to the economic well-being of the country based on the ratio "R&D investment cost/benefits obtained on rice productivity" and the IRR. It showed the importance of research in improving the productivity of the rice sector as well as the profitability of public investment intended for research and extension. The analysis tools used made it possible to measure the impact of research and extension on the profitability of the rice sector. Fall concludes that investment in research and extension is an interesting alternative for the use of public funds. In Burkina Faso, to ensure the support of decision-makers and that of local governments, Ouédraogo (2004) conducted an economic impact study of research on maize. The sorting rate was 81.28% found to demonstrate the profitability of investments in the varietal creation of corn during this period (1987 to 1997). He concludes that investment in research is more profitable than many public sector investments in Burkina Faso. Nikam *et al.*, (2019) assessed the economic impact of the mobile application using the economic surplus in Maharashtra, India. The results show that the adoption of the mobile application by 20% would generate a net social gain of 140.85 million euros and an NPV of 9,111.94 million euros. The internal rate of return would be 316%, which would suggest higher economic profitability of mobile application technology. On the other hand, for an application adoption level of 50%, the total net profit would be 13,271.42 million euros with an IRR of 317%. Wangithi's (2019) study showed that investment in IPM was viable with an NPV of $51.3 million (USD) over the 15-year projection, or approximately USD 3.4 million per year, an IRR of 60.3% in the assessment of the ex-ante economic impact of integrated management of citrus pests and diseases in selected counties in Kenya. In 2018, Souleymane and al. assessed the economic impact of cowpea research in Burkina Faso and found that the investment was very profitable with a sorting of 48% and an NPV of more than 121 billion over a period of 13 years (Souleymane and 2018).

2. MATERIALS AND METHODS

2.1. Data Sources

The data used as analytical support come from the Ministry of Economy, Finance and Foresight of Burkina Faso (MEFP-BF), the Ministry of Agriculture, Animal and Fisheries Resources (MARAH-BF) and of the Ministry of the Environment, Energy, Water and Sanitation (MEEEA-BF), the database of public agricultural and food expenditure (DPAA) for what concerns costs, popularization and research). At the MEFP level, data from the Computerized Expenditure Circuit (CID) database of the General Budget Directorate (DGB), the public investment program information base (PIP) and the Integrated Bank of projects (BIP) of the General Directorate of Economy and Planning (DGEP) and data from the Computerized Circuit of External Financing (CIFE) of the General Directorate of the Treasury and Public Accounting (DGTCP) were used. Agricultural data sizes, production, area, adoption rate, yield were obtained from agricultural statistics reports.

2.2. Model Choice

The essence of the concept of economic surplus in the field of assessing the impact of agricultural research is that the adoption of an improved technology variety allows one to produce at lower cost or to produce more at the same cost as with traditional variety technologies. It therefore leads to a reduction in production costs per unit of product, which results in a shift in the supply curve. This movement can be pivotal at the origin (Griliches, 1958; Akino and Hayami, 1975) or parallel (Masters and Sanders, 1994). The total benefit or gain from this shift is measured by the sum total of the changes in producer and consumer surplus. This method takes stock of the costs and benefits of the “Research and extension” investment.

The economic impact analysis is based on the theory of supply and demand. It is materialized by a diagram showing the movement of the supply and demand curves with the introduction of research. The result will be a shift in the supply curve thus revealing growth in supply through research. All other things being equal, any shift in the supply curve to the right is considered an increase in l supply due to the introduction of new varieties. As the introduction of new technologies is closely linked to the use of new varieties, the adoption rate will be defined as the proportion of area sown for the chosen variety in relation to the total area. Certain impacts induced by research (environmental preservation, sustainability, equity) are not taken into account by the economic surplus model (Crawford, 1993).

Our research will be based on the hypothesis of a parallel shift in the supply curve. It postulates that the adoption of an innovation causes a parallel shift of the supply curve from a0S0 towards a0''S2 (distance J) along the same demand line D0 (figure 1). The distance J measures the increase in production due to technology. This adoption requires an additional investment in inputs (seeds, fertilizers, phytosanitary products) represented in Figure 1 by the distance I. Taking into account J and I makes it possible to obtain the net shift of the supply curve of a0S0 towards a0'S1 (distance K) which is nothing other than the net gain in terms of reduction in production costs. With this movement of the supply curve along the same demand line D0, the social situation changes. This modification is measured in terms of variations in “economic surplus” which is nothing other than a measure of well-being. Therefore, at the initial market price P0, consumer surplus is equal to the area of triangle P0 in Figure 1 and producer surplus is equal to the area of triangle P0ea0 in Figure 1.

Another assumption of this model is the inelasticity of the supply and demand curves. The inelasticity of the supply curve is justified by the fact that the country will continue to import on the international market for a long time. Numerous constraints (land, liquidity and labor) limit the ability of producers to respond favorably to a short-term price increase. Therefore, price changes in the market will not noticeably affect the quantities demanded. The total net variation in economic surplus caused by a variation in supply is represented by the parallelogram a0efa0’ (in light gray in Figure 1) and the triangle efg (in dark gray in Figure 1). The sum of these areas represents the total ex-post increase in social profits (consumers and producers combined).

Calculating the economic surplus therefore amounts to finding the areas of the triangle and the parallelogram (Masters and Sanders, 1994).

The area of the parallelogram is equal to ef * Q0;

The distance ef = k represents the net gain in terms of reduction in production costs induced by the new technology. This distance is measured by the relationship k* P0 = (j/Eo)- c (Masters & Sanders, 1994), where k is the change in the net cost of production in proportion to the price of the product, P the real price to producers, j the proportional change in total production due to improved varieties, Eo the elasticity of supply and c the proportional cost linked to the adoption of improved varieties. The surface of the parallelogram is therefore equal to: k* P0*Q0; with Q0 the quantity produced of the product.

The area of the triangle is obtained by the formula 1/2ef * ΔQ = 1/2k* P0*ΔQ.

ΔQ being the difference between the quantities produced with improved varieties and traditional varieties (ΔQ = Q – Q0).

ΔQ = Q0 * Eo*Ed * k/(Eo+Ed). (Ed being the elasticity of demand and Eo that of supply).

The Gross Social Gain (GSB) is therefore given by the formula:

GSB = k*P0*Q0 - 1/2k*P0*ΔQ

GSB = k*P0*Q0 * (1 - 1/2(k Eo*Ed)/(Eo+Ed)).

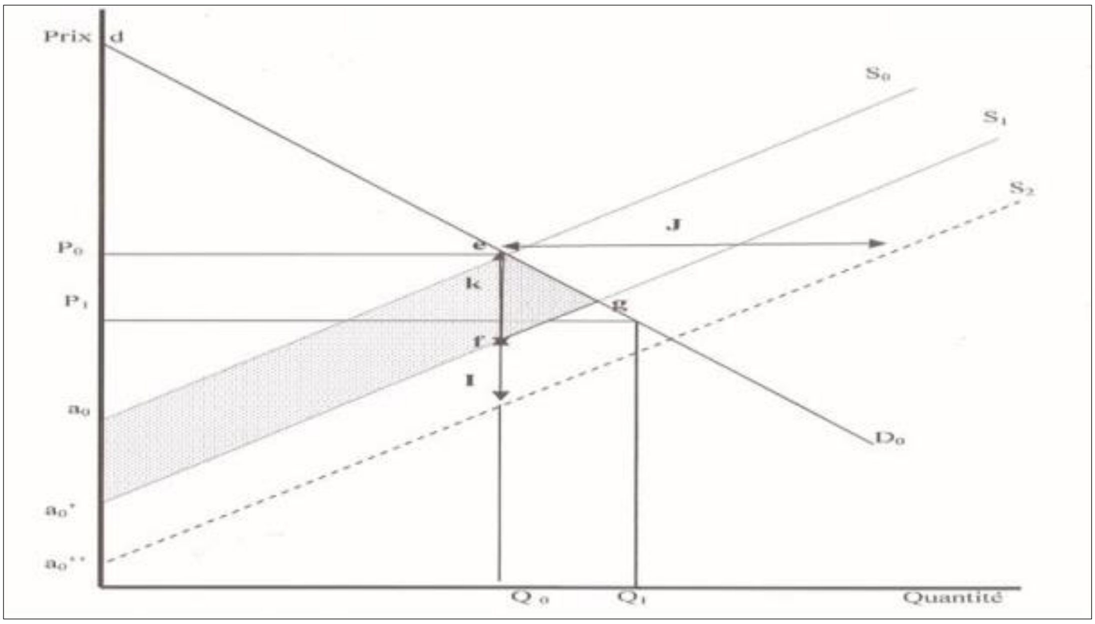


Figure 1. The economic surplus model

2.3. Empirical Model

As part of this research, the economic surplus model was used to measure the size and distribution of economic benefits that take into account changes in supply induced by agronomic research on sesame, the increase in demand due to improved quality and productivity and lower prices. The economic surplus model has been used by several authors including Master *et al.*, (1994), Ahmed *et al.*, (1995), Fisher *et al.*, (1995), Ouédraogo *et al.*, (1996, 2006, 2018), to assess the economic impact of agricultural research and extension. Since sesame is an export product of the country, foreign trade in sesame is very important. Thus, we are in an open economy where the equilibrium price is determined by domestic and external supply and demand. The model also assumes that sesame is marketed in a market in perfect competition where the price is determined by market laws and by perfect knowledge between producers and consumers. Additionally, it was assumed that the demand and supply curves are linear, with the supply curve shifting to the right with agricultural research. Building on the work of Alston *et al.*, (1995) and Wangithi (2019), the annual variation in consumer surplus (ΔSC), producer surplus (ΔSP) and total economic surplus (ΔSE) from the research is calculated as follows:

$$\Delta SC_t = P_0 Q_0 z(1 + 0{,}5Z_\eta) \text{ ………………………….. (1)}$$
$$\Delta SP_t = P_0 Q_0 (k - z)(1 + 0{,}5Z_\eta) \text{ …………………. (2)}$$
$$\Delta SE_t = P_0 Q_0 k(1 + 0{,}5Z_\eta) \text{ ………………………….. (3)}$$

With :
P_0 and Q_0, are the prices and quantity at the initial equilibrium;
k, is the vertical proportion of the shift in the supply curve attributable to the adoption of improved sesame varieties, expressed as costs per unit of production;

z, is the drop in price resulting from the shift in the supply curve;
η, is the absolute value of the price elasticity of demand and ε, is the price elasticity of supply;
The vertical shift of the supply function at time t (K_t) and the relative fall in prices (Z_t) are calculated as follows:

$$K_t = \left\{\frac{\Delta Y}{\varepsilon} - \frac{\Delta C}{1+\Delta Y}\right\} \times A_t \text{ ……………………………………. (4)}$$

Where :
ΔY, is the expected proportional variation in yield due to the adoption of improved sesame varieties
ΔY, is the expected proportional change in the cost of variable inputs with the aim of inducing the increase in expected yield.

A_t, is the adoption rate. That is, the proportional area of selected varieties of sesame to the total area of sesame. The level of adoption in a given year is estimated as follows:

$$A_t = \frac{M}{1+e^{(-a+bt)}} \text{ ……………………………………………. (5)}$$

This formula is transformed into an equation with the logarithmic function and the parameters estimated with the ordinary least squares (OLS) method (Wangithi, 2019). This equation takes the following form:

$$ln\frac{A_t}{M-A_t} = a + bt + \varepsilon \text{ ……………………………………. (6)}$$

With: M, is the maximum adoption rate; b is an adoption parameter; a is the constant; ε is the error term; t is the time in years; e is the base of the natural logarithm.

Furthermore, we mention other key parameters necessary for estimating the economic surplus: the research period, defined as the time allotted between the start of research until the availability of sesame varieties ready for popularization;

Research costs (RC), are the resources necessary for the development of sesame varietal creation, including the costs of its popularization. Data relating to research costs were collected from the INERA accounting department, taking into account the salaries of technicians and researchers, the annual budget for research projects on the varietal creation of sesame and the budget……

Extension costs (CV), extension services of the ministry in charge of agriculture of similar products (salaries of extension agents, fuel allocation and subsidy);

Market data includes data on the quantities of mangoes produced, the prices of mangoes, the elasticities of supply and demand in relation to prices and the discount rate. Elasticity is the proportional change in quantity induced by a change in price. Consequently, the elasticity of supply is defined as the proportional variation in the quantity supplied induced by a variation in price. The elasticity of demand is defined as the proportional change in the quantity purchased induced by a change in price.

The main parameters for updating the economic profitability of investment in research using the economic surplus model are as follows:

Net present value (NPV)

Net Present Value (NPV) is estimated using economic surplus and research expenditures to calculate benefits. It is calculated as follows:

$$VAN = \frac{\sum(\Delta SE_t - CR_t)}{(1+i)^t} \quad (7)$$

Where :

〖ΔSE〗_t, the variation in economic surplus attributable to the use of improved sesame varieties at time t;

〖CR〗_t, all research and extension costs linked to improved sesame varieties at time t;

i, the discount rate corresponding to the rate of return that could be obtained in a financial market with similar risks or the opportunity cost. The defined market i takes into account inflation over time t. NPV is assessed by calculating costs and benefits for a given investment period and the period is usually equal to one year (Wantigthi, 2019). Once the cash flow calculation for each period has been carried out, the present value (PV) of each of them is obtained by discounting the future value at a periodic rate of return dictated by the market. It is a simple and useful tool, which allows you to assess whether a project or investment will result in net profits or losses. Indeed, a positive NPV is equivalent to a net profit from the investment while a negative NPV is equivalent to a loss from the investment. In summary, the NPV is the sum of all discounted future cash flows i.e. the total economic value of profits minus costs and takes the following formula:

$$VAN = \frac{R_t}{(1+i)^t} \quad (8)$$

With, t representing the cash flow time and R_t, representing the net cash flow, i.e. cash inflows minus cash outflows at time t.

The Internal rate of return (IRR) is defined as the discount rate at which the NPV is exactly zero. In other words, the IRR measures the interest rate at which the present value of costs equalizes the present value of benefits, that is to say it represents the remuneration of investments made in research and popularization of improved varieties of sesame during a given period. It is evaluated by the following formula:

$$\sum_t^n = 1 - \frac{(R_t - C_t)}{(1+TRI)^t} = 0 \quad (9)$$

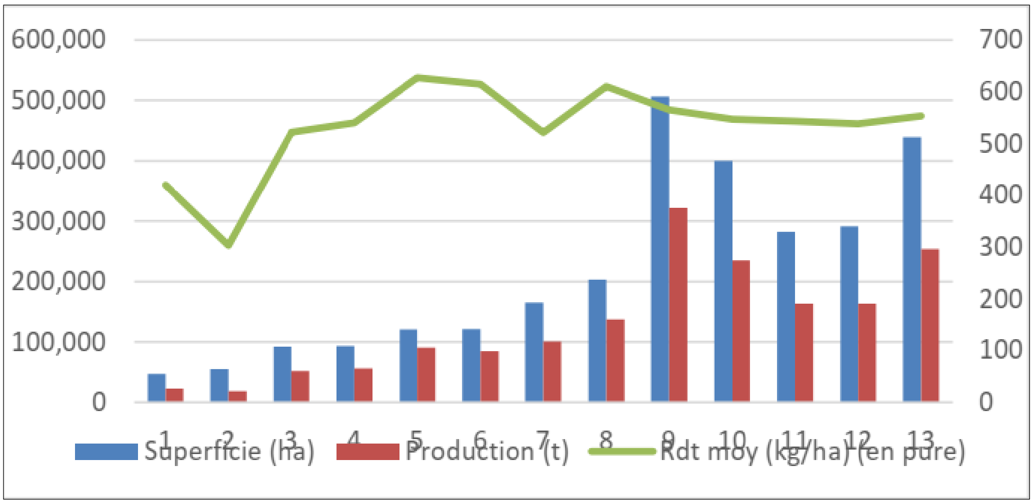
The IRR is generally used to validate a research program, that is to say if the IRR is higher than the interest rates practiced by commercial banks or the remuneration rates for private investments, it is relevant to indicate that the research program is a good investment. The IRR formula obtained by interpolation looks like this (Wantigthi, 2019):

$$TRI = \alpha + \left[\frac{VAN_a}{VAN_a - VAN_b} \times (b - a)\right] \quad (10)$$

Where: a, is the lowest discount rate; 〖NPV〗_a, is the NPV at the lowest discount rate; b, is the highest discount rate and 〖NPV〗_b, is the NPV at the highest discount rate.

3. RESULTS AND DISCUSSION

From 2006 to 2018, total sesame areas saw a significant increase; they increased from 47,337ha in 2006 to 438,941ha in 2018, an increase of 827% in twelve years. This spectacular increase in surface area can be explained by the existence of an internal and external market. Furthermore, the availability of improved varieties adapted to different agro-ecological conditions has favored the expansion of this crop. Yields of improved varieties vary between 600 and 800kg/ha in 2012 in real environments compared to only 150 to 350kg/ha for traditional (local) varieties (USA, 2018). This increase in national average yields, linked to improved varieties, combined with that of surface areas, has made it possible to achieve very high levels of production today. Thus, sesame production increased from 22,887 tonnes in 2006 to 235,936 tonnes in 2018 (more than 931% increase). Graph n°4 presents the evolution of surface areas, production and average yields from 2006 to 2018. All these quantities have experienced an upward trend in recent years. However, yields remain below the possibilities offered by agricultural research which is 1200kg/ha. This could be explained by the low rate of adoption of seeds of improved varieties.



Graph n°4: evolution of surface areas, production and average yields from 2006 to 2018.
Source: authors with data from MARHA, 2022

Research on sesame is an integral part of INERA's oilseed and protein program which includes research on peanuts, sesame, cowpeas, soybeans and voandzou. An annual budget allocation is made without dissociation in this program. Research activities on sesame do not occupy a preponderant place in this program, so much so that the related costs can be estimated at approximately 1/5 of the overall costs of the protein crop program of the plant production department of INERA. These costs include investment costs, equipment maintenance, operating costs and salaries (of researchers and technicians) paid from the national budget. Investment for sesame research relates, among other things, to the development of experimental fields and the acquisition of specific equipment for research. Observation of the results in table: 1 shows that these costs, although relatively low, are constantly increasing. This demonstrates the dynamism of researchers in mobilizing external resources through conventions and partnerships for the creation of varieties and the maintenance of existing varieties. Apart from staff salaries, direct state funding in the variety creation process has become rare so much so that researchers are turning to external funding. Following the end of PNDSA II in 2004, public spending on agricultural R&D fell until 2007, followed by a period of recovery that began in 2008 (Sp/Cpsa, 2013). Since 2004, the majority of research funding has come from bilateral and multilateral partnerships, through the signing of agreements and the financing of research projects, thus reflecting the spirit of the dynamism of researchers in the search for funding.

In the case of sesame, the cost of extension is made up of the amounts borne by the State for the acquisition of improved seeds for the benefit of producers, financing of the sesame sector through the private window of the Regional Decentralized Rural Development Fund (FR-DRD) of the “Decentralized Rural Development (DRD)” Component of PADAB 2. Also, numerous sesame sector projects have seen the light of day in recent years. All are financed by international development aid organizations: the PROFIL project, which aims to “reduce rural poverty by facilitating equitable access for the rural poor to agricultural sectors which benefit from buoyant markets”. This project is financed by IFAD (International Fund for Agricultural Development); the PAFASP project or Agro-Sylvo-Pastoral Sector Support Project, which is financed by the IMF (International Monetary Fund); the PDA or Agricultural Development Program, a German-Burkinabe cooperation which has chosen to focus on sesame; PADAB2 (Support Program for the Development of the Agricultural Sector in Burkina Faso), whose funds are Danish and; the RONGEAD/Inades Formation project, a project to support the development of local agricultural resources - sesame sector, with support from the European Union and de Broeder lijkDelen.

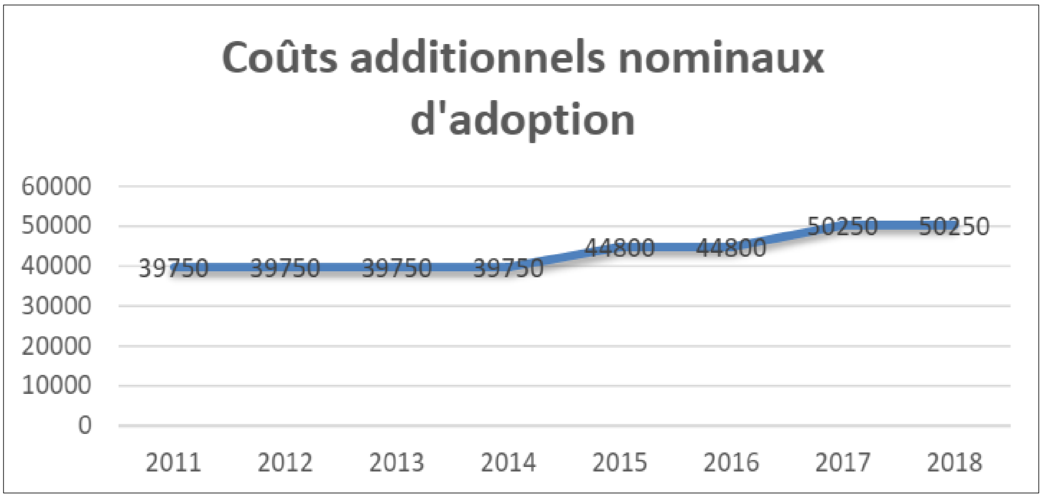
This list of programs providing technical support to farmers in general, and to sesame producers in particular, is not exhaustive. It allows you to get an idea of the plethora of projects and programs working to popularize sesame in Burkina Faso. Examination of table no. 1 below indicates a variation in the cost of extension from one year to the next. These costs range from 200 million FCFA to 718 million FCFA and this reflects the interest shown by the government and its financial partners in this speculation, a source of income for nationals (all actors in the sesame value chain) and currencies for the country.

Table 1: Costs of research and extension on sesame in Burkina Faso from 2006 to 2018

Année	Coûts nominaux de la recherche (FCFA)	Coûts nominaux de la vulgarisation (FCFA)
2006	75 907 604	434 906 877
2007	76 748 955	239 722 220
2008	82 329 480	278 688 375
2009	87 769 097	305 689 012
2010	128 923 836	435 803 959
2011	98 004 138	310 750 380
2012	120 118 859	496 245 439
2013	114 499 291	718 346 560
2014	73 030 702	381 094 925
2015	42 059 816	200 653 807
2016	100 937 343	500 307 887
2017	118 838 506	649 538 809
2018	92 545 253	704 951 476

Source: extracted from CID data and project and program reports, 2002-2022

The costs of adopting new technologies are the difference between production costs with and without research (production costs under improved variety minus production costs under traditional variety). By making the decision to adopt the new sesame variety, the producer must face a slightly higher production cost than usual (use of the traditional variety). In particular, it will bear the cost of acquiring the seed, that of fertilizers (increasing), phytosanitary products and salaried labor (increasing due to the use of fertilizers and application of insecticides). Indeed, improved seeds are accompanied by a technological package (technical itinerary, technical sheet) to best express their potential. The study by Ouédraogo (2003) shows that the adoption of improved varieties leads to an increase in production and labor costs of 3.7% on average in the areas studied, i.e. a net increase of 23,400 FCFA per hectare planted with improved cowpea varieties. However, the gains generated by these largely offset these costs (increase in gross margin per hectare of more than 101%). For improved varieties of sesame, the estimate of additional costs is around 40,000 FCFA, graph.



Graph n°5: evolution of the costs of adopting improved sesame seeds.
Source: authors

Prices to sesame producers vary from one year to the next (table no. 2). This price variability could be explained by the fluctuation of market demand over the years. Indeed, international demand has been the greatest determining factor in the evolution of the producer price of sesame in Burkina

Faso during the last campaigns. In fact, the minimum prices increased from 220 FCFA in 2015-2016 to 450 FCFA in 2020-2021. As for maximum prices, they increased from 480 FCFA in 2015-2016 to reach their peak at 750 in 2016-2017 before falling to 580 FCFA in 2020-2021 (Apex, 2022). In principle, making improved varieties available should increase production and therefore reduce prices to producers. But, exports would contribute to increasing prices and providing foreign currency for the country. It is very important to take inflation into account by dividing the observed costs (costs of research, sesame popularization, sesame price and additional adoption costs) by a consumer price index, to that costs are expressed in constant terms for each year considered. The harmonized price index therefore transforms nominal values into net values. This index is defined as being equal to 1 for the given base year which is 2018 in the context of this study.

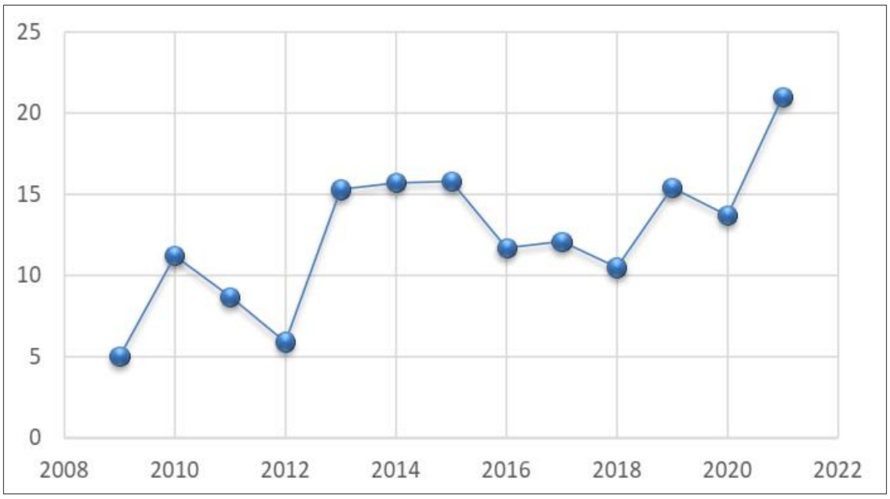
The elasticity of supply (ε), defined as the proportional variation in the quantity produced, induced by the corresponding variation in price of 1%, reflects the relative difficulty of producers to increase production (limited available resources). Normally, the estimated values of supply elasticity are between 0.2 and 1.2. The elasticity of demand (e), defined as the proportional change in the quantity consumed, induced by a 1% change in price, reflects the relative preference of consumers for an increase in consumption. Normally, estimates of the elasticity of demand vary between 0.4 and 10. In the absence of information on elasticities specific to Burkina Faso, those used for the sub-region of Sub-Saharan Africa were considered. They are 0.8 for supply and 0.4 for demand (ALLAWANGAYE, DJOULET, KOMUA, & vVANDOU, 2001). In other words, a 1% increase in price leads to an increase in supply of 0.8% and a reduction in quantity demand of 0.4%.

Table 2: Evolution of prices per ton of sesame

année	**IPC (Base:2018=100)**	**Prix réels du sésame (P) (FCFA/T)**	**Elasticité de l'offre(ε)**	**Elasticité de la demande(e)**
2006	66,53835579	357 688	0,8	0,4
2007	65,62184951	350 493	0,8	0,4
2008	80,92750435	352 167	0,8	0,4
2009	83,76867382	674 476	0,8	0,4
2010	82,30226377	746 031	0,8	0,4
2011	90,27586839	577 120	0,8	0,4
2012	95,04170104	641 824	0,8	0,4
2013	94,67509852	596 778	0,8	0,4
2014	91,65062781	596 832	0,8	0,4
2015	93,9418935	578 017	0,8	0,4
2016	94,85839978	567 161	0,8	0,4
2017	96,71890752	571 760	0,8	0,4
2018	100	644 000	0,8	0,4

Source: authors based on data from the BCEAO, SO.NA.GE.S.S.

The adoption rate is the ratio of the area planted with improved sesame varieties to the total area of sesame. Note that the adoption rate in terms of cultivated area could be very different from the adoption rate in terms of the number of farmers who adopted the technology, since different producers cultivate different areas. It is essential to try to estimate adoption carefully, using the best information possible. In our study we use the estimate of the rates carried out by the specialized services of the Ministry of Agriculture (Marah/Dgess, 2022), graph n°6 this rate has an upward trend over time but remains very low less than 50 %, critical rate to really boost production and even food security (Masa, 2013).



Graph n°6: Evolution of the adoption rate of sesame varieties in Burkina Faso from 2009 to 2021.
Source: Authors

The proportional increase in costs linked to the adoption of improved varieties is given by the following formula: c = (□C x t)/(R x P) with □C as the increase in production costs per hectare due to the adoption of the variety, t the adoption rate, R the average yield and P the real price per ton of sesame.

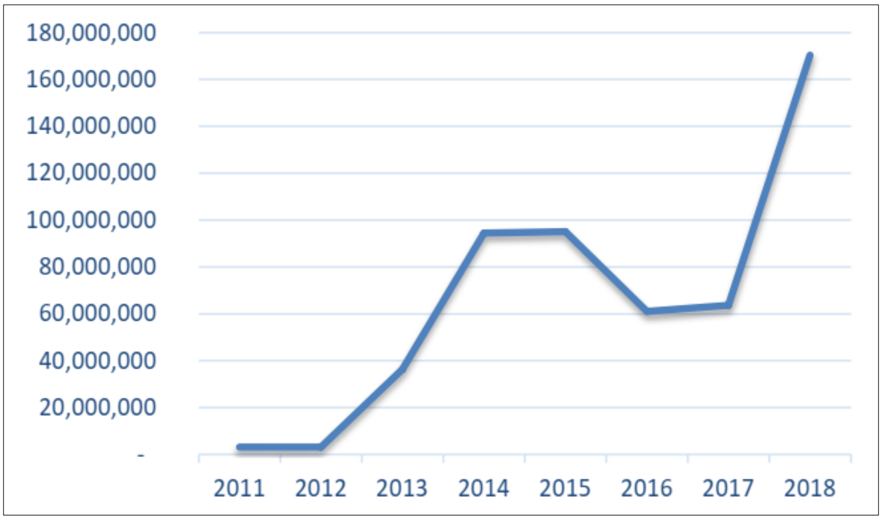
The adoption of improved varieties provides a yield gain ranging from 900 to more than 2150kg per hectare. These varieties have high agronomic potential (Palé *et al.*, 2009). The adoption of the BO NOGORA variety (SKC21GMP3) generates the highest production gain, i.e. more than 100%. Furthermore, these varieties are more adapted to changing agro-climatic conditions than local varieties.

The replacement of the net cost of production as a proportion of the price is an indicator is given by the following formula:

k= j/□ – c where (□) is the elasticity of supply; j, production gains and c, proportional adoption costs. k represents the net reduction in production costs induced by the new technology.

The evolution of k, a shift in supply following the use of new varieties of sesame, is represented by graph 7.

The increase in production corresponds to the change in the equilibrium quantity (ΔQ). Indeed, the introduction of improved sesame varieties increases the quantity produced, resulting in a new balance on the sesame market. It is given by the following formula: ΔQ=Qeεk/(e+ε). The graph shows that from 3 thousand tonnes in 2011, the increase in production increased to 176 tonnes in 2018, which reflects the continued diffusion/adoption of new varieties.



Graph n°7: Evolution of the increase in production following the adoption of improved sesame varieties in Burkina Faso.
Source: Authors

The gross social gain is the estimate of the economic benefit provided by research on sesame and the diffusion/adoption of new varieties (table 8). The gross social gain is given by the formula:
GSB= k*P*Q-1/2*k*P*ΔQ

The net social gain (GSN) is the net benefit provided to society by the diffusion/adoption of new sesame varieties. This gain is the difference between the GSB and the costs of sesame research and popularization.

From where:
GSN= GSB - total net costs (research and extension)

Examination of table no. 3 indicates that from 2006 to 2010, the net social gain is negative reflecting that during this period, research did not provide any benefit. In fact, these years correspond to the period of research in laboratories to produce improved varieties. As a result, there is no transfer to the peasant environment at this time. From 2011, varieties were obtained and transferred to farmers so that the net social gain was positive. Also, price instability as well as investments in research and extension are not stable, social gains vary depending on the years. Observation of the table shows that during the first years following the introduction of a new sesame variety, adoption levels are low. Changes in supply and the parameter K, shift in supply following the adoption of new varieties, are then small. As adoption grows, economic surplus grows exponentially. Therefore, the greatest gains will be made when diffusion becomes widespread.

Table 3: Estimate of net social gains following the adoption of improved sesame varieties

année	Gains sociaux nets
2006	- 5 373 894 989
2007	- 3 375 854 598
2008	- 3 122 702 233
2009	- 3 287 871 990
2010	- 4 803 141 963
2011	5 521 114 876
2012	2 931 573 248
2013	88 625 655 211
2014	240 717 358 650
2015	220 587 704 583
2016	109 159 966 583
2017	120 069 766 810
2018	267 840 496 195

Source: Authors

Our research found that the calculated internal rate of return (IRR) is 69%. This rate represents the interest earned by the resources engaged in sesame research and popularization in Burkina Faso from 2006 to 2018. The interpretation of TRI is done by comparing it to the borrowing interest rate i applied by the institutions microfinance in the study areas (Yabi, 2012). If IRR > i then the activity is economically profitable from the point of view of capital investment. On the other hand, if TRI < i, then the activity is not economically profitable from the point of view of capital investment. 69% is well above any credit rate in microfinance structures. Investment in sesame research and popularization activities is therefore very profitable with a profit-on-cost result of 69 francs for 100 FCFA invested. A producer can take out credit in microfinance structures where the maximum interest rate is 22% (Traoré, 2018) and benefit from sesame production with improved varieties.

The NPV measures the excess of benefits over the costs of a project when the latter are evaluated on the basis of a given interest rate. At the bank rate of 10% the NPV is equal to nearly 372 billion FCFA; research and extension on sesame produced a net profit in 2018 of nearly 372 billion FCFA for a cumulative investment of 54 billion FCFA between 2006 and 2018 in Burkina Faso. This sum is not physically available in the accounts of a structure or a third party. It represents all the profits that producers gain following the increase in their production and those that consumers also gain following the combined effects of the availability and the fall in the price of sesame.

The research contributed to a significant increase in national sesame production. Indeed, the increases in yields have been considerable. Sesame yield increased from 1000kg/ha in 2006 to 2600kg/ha in 2018 (potential) and from 850 to 1500kg/ha in a farming environment. This increase reflects the research effort through the dissemination/adoption of these results to make food available to the population. Yield gains have attracted more producers and, as a result, an increase in surface areas and quantities produced. Thus the areas increased from 47,337 ha (in 2006) to 438,941 ha (in 2018). Therefore, large-scale adoption would be a good alternative to sustainably increase food security. This is all the more important as in the fight against food insecurity, the results obtained here show that investing in agricultural research is a sure way to achieve this.

The contribution of research to improving food security has not only been the provision of varieties with high yield potential to populations but much else. It has also generated varieties resistant to crop pests and adapted to the different agro-ecological zones of the country. It has even developed conservation mechanisms and tools (such as pick bags) for the harvest which allow the product to be available for a long period without the use of chemicals dangerous to health. It should be noted that to meet quality requirements, the selection of varieties is done in a participatory manner with the producers who therefore define the desired product quality (texture, seed size, taste, etc.).

CONCLUSION AND POLICY IMPLICATIONS

The results of this study show that investments made in research and popularization of improved sesame varieties are profitable and have a real impact on production. In fact, the yield has increased significantly since the beginning of agronomic research on sesame. The adoption of new technologies has facilitated the evolution of production systems towards sustainability: from family farming to production intended for the national and sub-regional market. Also, these investments generated an internal rate of return of around 69%. This result confirms the success of the research carried out in relation to an effective technology transfer system. The net benefits for society are nearly 372 billion CFA francs in 2018 and thus reflect the impact on the well-being of the population as a whole following agronomic research on this speculation. The investments that have been made have therefore been more than profitable and will continue to be highly beneficial for society in solving the problems of food insecurity and poverty. It is therefore necessary to continue to invest in the creation/adoption of new varieties.

These results also make it possible to support that the seeds of popularized improved varieties correspond not only to the needs of producers, but also that they adapt to their socio-economic conditions. Support for agricultural research on sesame should continue in order to consolidate the results achieved and meet new challenges. Indeed, this considerable and constant increase in yields and areas will require a concerted research effort to continue the development of improved and adapted varieties and production techniques. The main result highlighted in this study makes it possible to identify some economic policies so that the State and its partners can reconsider and increase the portfolio allocated to research in Burkina Faso for sustainable development. They are as follows: (i) Improve access and accessibility to agricultural credit by farmers so that they have the necessary means to invest properly in the adoption of improved seeds; (ii) Permanent funding for research will make it possible to have a global research strategy to support the country's development objectives; (iii) the mobilization of substantial funding will allow research to generate more technologies and innovations for the benefit of producers and ultimately an increase in production which will allow consumers to have quality food at lower cost. Vulnerable sections of the population could access food at lower cost.

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