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RESEARCH ARTICLE

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The impact of access to agricultural advisory services on input use and farm performance: Evidence from Senegal

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Abstract

Performant agricultural advisory services (AAS) in Africa are crucial for improving the agricultural productivity and food security of the farm households. Yet, evidence-based study on the impacts of AAS on farm performance are scarce, especially in West African countries. This study evaluates the impact of access to AAS on input use and farm performance in Senegal, employing the instrumental variable and control function approaches accounting for selection bias. The approaches are also employed to several sub-samples to see if the impacts are heterogeneous across crop types and fertilizer use, and matching techniques are applied to test the robustness of the results. Results show that the highest positive impact of AAS is on yield, while the impacts on gross margin and improved seeds uptake are very modest. Access to AAS has no effect on fertilizer uptake. It also finds that AAS impacts positively cereal production and farmers using no fertilizer but has no effect on the legume and horticultural crop production and on farmers using fertilizer. Given the Senegalese government and donors have put a lot of effort into developing an efficient AAS system, a consideration of the identified

Abbreviations: AAS, agricultural advisory service; AME, adult male equivalent; ANCAR, Agence Nationale de Conseil Agricole et Rural; CF, control function; IV-2SLS, instrumental variable–two-stage least squares; PAPA, Projet d'Appui aux Politiques Agricoles; PO, producer organization; SAED, Société d'aménagement et d'exploitation des terres du delta et des vallées du fleuve Sénégal; SRDR, Sociétés Régionales de Développement Rural; SSA, Sub-Saharan Africa.

weaknesses is required to improve its efficiency. [EconLit Citations: Q12, Q16]

KEYWORDS
advisory services, economic performance, impact assessment, land productivity, Senegal

1 | INTRODUCTION

Given the dynamic population growth in sub-Saharan Africa (SSA), the demand for food in the continent may triple by 2050 (van Ittersum et al., 2016) and how to feed the growing population is becoming a crucial challenge (HLPE, 2013; World Bank, 2008). In addition, with land degradation and growing environmental concerns, crop intensification is expected to happen with sustainable production methods applied at both farm-level and beyond the farm. For this reason, governments and international donors increasingly support the access of farmers to agricultural advisory services (AASs). AASs can make an important contribution to the sustainable intensification of production by improving diffusion of scientific and technological knowledge, helping farmers to acquire the technical skills required to apply modern and more sustainable technologies, and through a more efficient use of agricultural inputs (Birner et al., 2009).

As originally recognized, agricultural extension means to "extend" research-based knowledge to the rural sector to improve the lives of farmers and has mainly focused on increasing production, improving yields, training farmers, and transferring technology (Davis, 2008). Over the decades, extension services have evolved in different directions according to the countries and the reforms undertaken, becoming a more holistic concept and leading researchers to prefer the term of "advisory services" rather than "extension services" (Birner et al., 2009; Faure et al., 2012). The actors providing advisory services are not necessarily from the public sector but can belong to the private sector, nongovernmental organizations, farmers organizations, or a mixture of these (Feder et al., 2011). Furthermore, the scope of the support is not necessarily focused on aspects of production and can be extended to other aspects such as sustainability, marketing, gender, nutrition, and health issues (Birner et al., 2009; Kilelu et al., 2014). Lastly, the method by which the service is provided can be based on a classical transfer of information (from extension agents to an individual farmer or group of farmers) or based on more innovative learning processes (Faure et al., 2012; Niu & Ragasa, 2018).

Although a wide variety of approaches to advisory services exists in SSA, the original model still seems to prevail with the primarily focus being on increasing agricultural productivity, adopting innovative technologies, and improving farmers' income (Birner et al., 2009; Faure et al., 2012; Niu & Ragasa, 2018). Moreover, there is contrasting evidence in the literature about the achievement of these objectives (Anderson, 2004).

In Ethiopia, Dercon et al. (2009) found that receiving at least one extension visit reduces poverty by 9.8 percentage points. Using the same panel survey but on later waves (1999, 2004, 2009), Krishnan and Patnam (2014) found that advisory services produced significant increase in improved seeds and fertilizer adoption in the earlier wave (1999) but the effect wore out in the later years despite a considerable increase in the number of extension agents. Still in Ethiopia, Buehren et al. (2019) found that an advisory services program implemented in 2006 has led producers to farm more marketable crops. Conversely, in Malawi, Ragasa and Mazunda (2018) did not find the implemented advisory services had any effect on the adoption of seeds or fertilizer, the productivity of corn and legumes, and food security once they account for the fertilizer subsidy program that could otherwise overestimate the impact of advisory services. Benfica et al. (2019) developed a mixed method combining ex post and ex ante analyses to assess the distributional effect of Mozambique's investment plan and found that the resources would have been better used if they had been allocated to agricultural research and advisory services.

Other studies have assessed the impact of more local and generally more innovative advisory services. Nakano et al. (2018) showed that a farmer-to-farmer extension in an irrigation scheme in a district of Tanzania allowed targeted technologies (modern rice variety, fertilizer, bund construction) to diffuse gradually over years and contribute to increased rice yields. Bellemare (2010) in Madagascar found that the number of visits from technical assistants organized by a private processing firm had a positive effect on the yields of green vegetables.

Empirical literature on AAS in West African countries is scarcer. In Nigeria Wossen et al. (2017) found that AAS enhances the adoption of improved cassava seeds by 12%. In Ghana, Emmanuel et al. (2016) found a positive effect of access to AAS on fertilizer use (+37%) and rice yield (+15%). In Senegal, Franzel et al. (2018) conducted a qualitative diagnostic assessment of AAS by providing a comprehensive overview of the current system in place. The objective was rather how to improve access to and the efficiency of the current AAS in place than to assess the actual impact on farms. Despite an important AAS system provided by national and regional agencies for several decades in Senegal, there is no ex post impact assessment of the AAS system on farm performance.

This present study presents the first attempt to provide empirical evidence of the impact of farmers' access to AAS on improved seeds and fertilizer uptakes and on farm productivity and income in Senegal. There is in Senegal a strong public support from the government to enhance the access of farmers to agricultural inputs, mainly seeds and fertilizer, through an input subsidy program (Seck, 2017). As shown by Ragasa and Mazunda (2018), in such a policy environment, the interplay between the two programs has to be accounted for to avoid bias in the impact estimated, because the factors explaining who receives subsidies are usually similar to those explaining who gets access to AAS. Therefore, we account for the input subsidies when estimating the impact of farmer access to AAS. Also, the content of the advice provided by the extension staff could be better adapted to specific crops than others. The advice dispensed could also be more or less relevant according to the group of farmers considered. We account for such potential heterogeneous effects as it might be more helpful for policy-makers and donors willing to improve the AAS system in the country. Eventually, this study also aims to contribute to the literature by taking advantage of a nationally representative survey that comprises almost 6000 farms covering all the regions of Senegal.

2 | THE AAS IN SENEGAL

The institutional framework established in Senegal to provide AAS to farmers has evolved in three main phases (Ndiaye, 2013). From 1960 to 1990 extension services were linked to either integrated rural development project (PDRI) or regional rural development agencies (Sociétés Régionales de Développement Rural [SRDR]). They were targeted to support production and marketing of cash crops (groundnut, cotton, and so on) (Ndene, 2020). The SRDRs were the public structures in charge of the design and the implementation of the extension services, and broadly responsible for implementing agricultural development projects, mainly through the distribution of inputs (seed and fertilizer). Their role later became increasingly large and complex, as they were responsible for promoting integrated rural development by focusing on production, small-scale food processing, literacy, and gender issue, among others (Faye, 2005).

From 1990 to 2000, the SRDRs adopted the Training and Visit extension system promoted by the World Bank, where extension agents trained groups of farmers in new technologies. Given the low impact of this top-down method, but also on the request of farmers to fill the void after the dissolution of several SRDR a few years earlier, in 1999 the Government created the National Agency for Rural Advisory Services (ANCAR). The objective was then to change the extension approach towards a more decentralized, pluralistic (different actors involved), participatory, and demand-driven services (Agunga et al., 2014). This agency is still the main organization for promoting and coordinating the national system of AAS. It is a parastatal agency where the two main shareholders are the state and producer organizations (POs), which respectively hold 42% and 38% of the capital (Inter-reseaux, 2021). ANCAR is composed of a central management, coordinators at the district level, and 94 teams of agents present in all the regions (about six teams per region) supporting all of the value chains of the country.

The primary focus of ANCAR is on the use of modern inputs, especially improved seeds, and their recommendations concern almost exclusively the goal of increasing crop yields (Ndiaye, 2015). Nevertheless, the agency also provides some support on aspects of marketing with agents providing local market information to farmers and linking the latter to the largest cereal buyers of the country (Simpson, 2012). Other thematic areas such as nutrition, health, adaptation to climate change, and natural resource management are not emphasized by the agency (Franzel et al., 2018). The approach taken by ANCAR is supposed to be demand-driven and participatory but the agency has been criticized for the limited knowledge of the extension agents in actually setting up participatory methods with farmers. The lack of human and financial resources has also been identified as a significant problem. Furthermore, missing are training of the agents in communication and facilitation, “soft skills” essential in promoting new technologies or strengthening the capacity of farmers to management and marketing (Franzel et al., 2018).

In addition to this central agency, there are two other regional agencies, SAED[1] in the north and SODAGRI[2] in the south, which significantly contribute to the implementation of the AAS in the country. Their main mission is to develop and maintain large hydraulic installations. They also provide a significant range of support to farmers through the implementation of AAS to ease the adoption of technology adapted to irrigated crops (mainly rice). The third type of actor providing AAS to farmers are development projects funded by international donors (nongovernmental organizations and international agencies such as United States Agency for International Development [USAID]). The AAS methods used are usually more innovative than those used by the previous actors but are usually of limited duration and on particular areas or topics.

3 | CONCEPTUAL AND EMPIRICAL FRAMEWORK

Motivation to participate to AAS may differ across farmers because of heterogeneity in the institutional and political environment, farming systems, market access, resource endowment, farmers' profiles and objectives. For instance, policies such as the agricultural input subsidy program may affect the likelihood that farmers will participate to AAS (Ragasa & Mazunda, 2018). Indeed, as farmers have available subsidized fertilizer, they may be more prone to improve their ability to use the inputs knowledgeably to increase their productivity and as a result their income. Similarly, farmers’ motivation may change according to the crops cultivated or the practices already in use on the farm. Participation in AAS, in turn is expected to affect farmers’ decision-making processes, analytical skills, and a reduction of information barriers associated with farming practices and technology that are encouraged by the agency in charge of the AAS (Balaine et al., 2023; Davis et al., 2012). Hence, if we assume that the mentioned factors affect access to AAS, we expect this access to influence positively the decision to adopt innovations such as improved seed varieties and fertilizer which in turn might affect positively farm performance. Figure 1 summarizes the hypothesized impact pathways from the factors affecting AAS to input use and farm performance. In our analysis, we consider the listed factors as contributors to the decision to participate in AAS. We also consider the pathways through which participation in AAS affects farm performance by adding innovation adoption variables such as the use of improved seed varieties and fertilizer.

3.1 | Estimation strategy

To identify the causal relationship of access to AAS on outputs of interest, an ideal experiment would be to randomly select villages and households that would benefit from AAS and where each recipient would be advised on a specific crop (or crop type). This random setting would ensure that the effect of the service on a specific group

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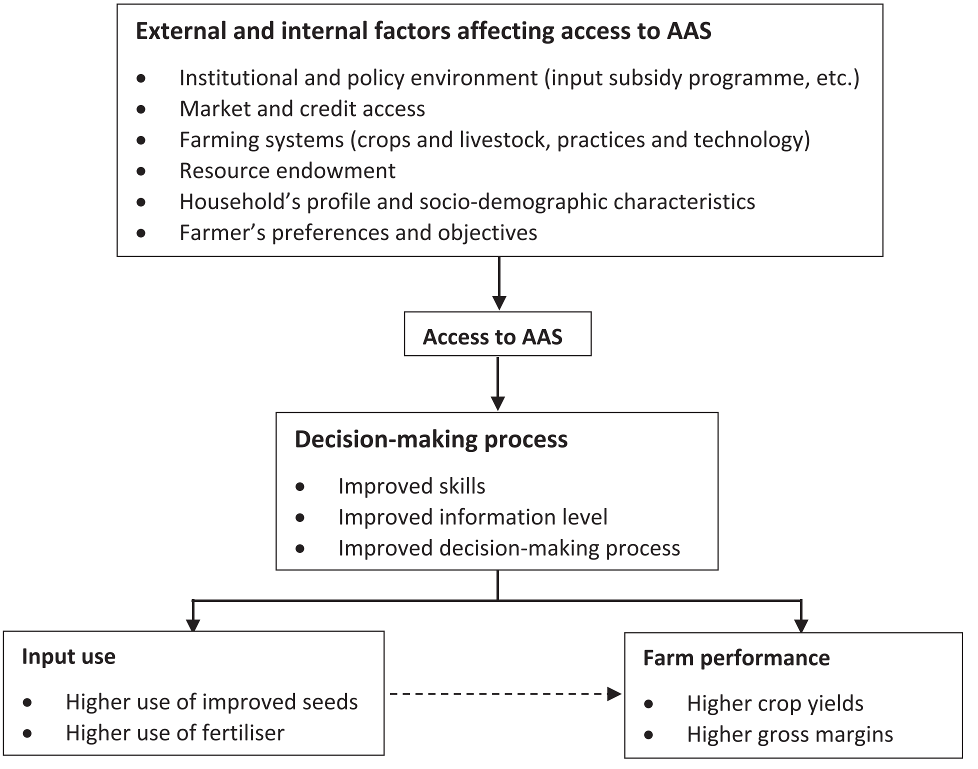

FIGURE 1 Hypothesized impact pathways from the factors affecting access to Agricultural Advisory Service (AAS) to input use and farm performance. *Source*: Authors elaboration based on Birner et al. (2009) and Balaine et al. (2023)

of crops can be assessed easily by applying a simple regression using the ordinary least squares (OLS) estimator. The structural equation would be:

$$y_{ijsk} = \beta_0 + \alpha D_i + \gamma X_{ijsk} + \delta W_i + d_j + d_s + d_k + \mu_{ijsk}, \tag{1}$$

where y_{ijks} is the output variable of interest related to the crop j cultivated by the farmer i in season s in district k, D_i is a dummy equals to 1 if the farmer i is recipient of the service, X_{ijsk} is a vector of control variables at individual-crop-seasonal-district level, including the use of various inputs such as the amount of seed used and the fertilizer applied, W_i is a vector of household characteristics, d_j is a vector of crop dummies, d_s is a vector of seasonal dummies, d_k is a vector of district dummies, and μ_{ijsk} is an i.i.d. error term that is distributed normally with mean zero and variance σ.

Nevertheless, access to AAS is not random in our empirical setting. The AAS system in Senegal suffers from a lack of financial and human resources so that it is highly probable that the extension effort across districts is not random but done according to specific criteria such as expected agronomic responses to the technologies promoted, current adoption rates of the technologies, and so on. This placement effect is controlled for with district dummies (d_k) that account for unobserved heterogeneity between districts.

Furthermore, the farmers of the beneficiary villages may decide to receive or not support from extensionist agents according to their own expectations of the benefits it could bring. Selection criteria used by the extension agents may also influence who are the recipients of the AAS. It turns out that unobservable variables such as ability and motivation may affect both the decision to participate in AAS program and the final performance outcome leading to biased coefficient estimates in a standard regression model. Without accounting for the selection bias, the effect of the program measured by the parameter of interest α could be due to unobservable confounding factors rather than resulting from the program itself. Given the cross-sectional nature of the data, we use two alternative approaches to correct for the endogeneity and obtain robust less biased measurements of the impact of access to AAS. The two-stage least squares instrumental variable (IV-2SLS) approach is used first and consists of using additional variable(s) Z that must affect the endogenous variable (*D*) but must be uncorrelated with the error term μ from Equation 1. In the first stage, a reduced form equation where *D* is regressed on the instruments *Z* and all the exogenous variables from Equation 1 is estimated as follows:

$$D_i = \phi_0 + \phi_1 Z_{isk} + \phi_2 X_{ijsk} + \phi_3 W_i + d_j + d_s + d_k + \varepsilon_{ijsk} \tag{2}$$

The reduced form equation of *D* leads to the calculation of the fitted values $\hat{D}$ uncorrelated with μ. In the second stage, $\hat{D}$ is used in the structural Equation 1 instead of *D*. The two-stage least squares estimator (IV-2SLS) is used to estimate the parameters of the two stages.

Given that the endogenous variable *D* is dichotomous, an alternative approach is to use a binary response model in the first stage. This method is called control function (CF) approach and is similar to IV-2SLS approach because it requires the identification of at least one instrument. In the first stage Equation 2 is estimated as a probit model and generalized residuals ($\hat{gr}_{ij}$) of the regression are then calculated as follow (Wooldridge, 2015):

$$\hat{gr}_{ij} = D_i \lambda(.) - (1 - D_i)\lambda(.) \tag{3}$$

Where $\lambda(.)$ is the inverse Mills ratio. In a second step, the generalized residuals are included in the structural equation to control for the endogeneity of D while the instrument is excluded. The significance of the parameter on the residual is a test of the actual correlation between D_i and μ_{ijsk}. A difference with the IV-2SLS is that the CF approach exploits the binary nature of D, which is likely more efficient, but less robust (Wooldridge, 2015). For more details on these two methods and their comparison, see Wooldridge (2015).

The estimation of the impacts on the whole sample, where all the crops are pooled, implicitly assumes that there are spill-over effects at the household level between the major crops, which are the main focus of the agricultural advice dispensed and the minor crops. Yet, this is not necessarily true and access to an AAS program may affects the performance on certain types of crops only. It could also affect farmers according to certain specific characteristics. To consider those aspects and gain additional insights, the analysis is extended to several disaggregated models. First, we test for the effect of access to AAS for different crop types: rainfed cereals (millet, sorghum, corn), irrigated cereals (paddy), legumes (groundnut, cowpea), and the main horticultural crops cultivated (onion, tomato, cabbage). Second, we split the sample between farmers who do not use fertilizer and those who use it.

3.2 | Identification strategy

The two methods used in this study requires at least one instrument. We follow Ragasa and Mazunda (2018), who have shown that the percentage of farmers receiving advice in the municipality, minus the respondent, is a valid instrument. This instrument captures the unobserved criteria used by extension officers when selecting the villages and households, and is positively correlated with the probability that a farmer will access the AAS. It also captures farmers' decision to participate to AAS due to peer effect.

It can be argued that larger values of this instrument (areas with a large share of recipients) correspond to areas with greater agricultural potentials translating to higher input use and performance. The district dummies added to the model account for this unobserved heterogeneity and, in the case of performance indicators, control variables on input use are added to the model. Also, the use of this instrument implicitly assumes a limited dissemination of information and advices received by the recipients of the AAS to other farmers of the same village, whereas according to the literature this assumption may not hold for period longer than a year (Conley & Udry, 2010; Nakano et al., 2018). This drawback can be made for any quasi-experimental method attempting to capture the effect of access to AAS on farmers, and, in a cross-sectional setting, it can be assumed that the advices provided in a particular year might spread in a limited extent within that same year. Still, we partially control for this channel through the introduction of the control variable "being a member of a PO," as the flow of information between farmers may be higher when they are members of a same PO. In final, if this implicit assumption does not entirely hold, the choice of this instrument would lead to an underestimation of the benefits of the Senegalese AAS system. This is why we provide in Appendix C estimates of the impact based on matching techniques that control for observables and do not require an instrumental variable. To further validate the instrument, we conducted the falsification test proposed by Di Falco et al. (2011): to be valid, the instrument should affect the participation decision but not the outcome variables. Results of the Probit estimation to explain access to AAS (Table 3) confirms that the instrument affects positively the access to AAS. The F-statistic associated with the first-stage instrument's coefficients are always much larger than 10, the usually accepted threshold at which the instrument is considered as strong (see Table 4). The F-statistics are also compared with the critical values from Stock and Yogo (2005) for testing weak instrument. The statistics easily exceed the critical values so that we can conclude that our instrument is relevant. When the instrument is included in OLS regressions on the outcomes of interest, the instrument has no significant impact (see Appendix A).

4 | DATA AND DESCRIPTIVE STATISTICS

4.1 | Data

We use farm household and crop-level data from the project called Projet d'Appui aux Politiques Agricoles (PAPA), an initiative of the Government of Senegal funded by USAID under the "Feed the future" initiative and implemented for a period of 3 years (2015–2018) by the Ministry of Agriculture and Rural Equipment.[3] The nationally representative survey was administered during the growing season 2017 following a multistage sampling procedure to select a total of 6150 farm households covering all the regions of Senegal and 42 districts. After excluding the very marginal crops with <20 observations in total and after dropping 416 households due to missing information or unrealistic outliers, the sample reduced to 5733 households and 11,794 observations at the crop level, covering all the regions and 38 districts.

The PAPA survey collected detailed information on demographic and socioeconomic characteristics, crop acreage and production, input use, sales, and off-farm income-generating activities. The survey also gathered information on recipients of the input subsidy program, access to credit, membership of PO, and lastly, access to AAS. Figure 2 provides an overview of the geography of access to AAS by displaying the percentage of farmers who have access to AAS at the district level.

It can be observed that the districts with the highest rates are in the north of the country (along the Senegal River Valley) where more than 25% of farmers have access to AAS in each district, and the south (along the Casamance River) even if the rates are more heterogeneous across the districts. These higher rates are explained by the presence of the regional agencies—SAED and SODAGRI—offering AAS to farmers in these two valleys (see Section 2). In the groundnut basin, which is an important agro-ecological area in the centre of the country, the access' rates are also heterogeneous between districts.

[3]There is no online access to the data but there are available upon request to astou.diao@isra.sn. The Institut Senegalais de la Recherche Agricole (ISRA) was one of the partner structures leading the survey data collection.

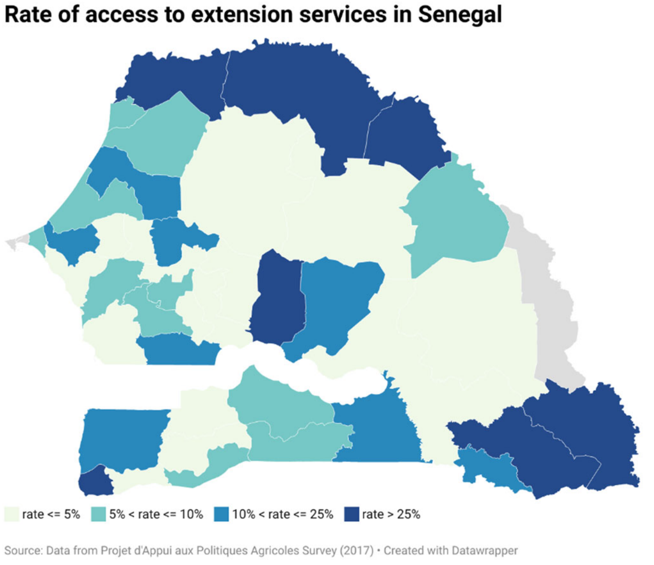

FIGURE 2 Rate of access to extension services in Senegal. *Source*: Data from Projet d'Appui aux PoliSques Agricoles (PAPA) survey (2017).

4.2 | Outcome variables and explanatory variables

The outcomes of interest are related to farmer's uptake of improved seeds and fertilizer, and farm's performance. Improved seeds and fertilizer are modeled as binary variables in the models on input uptake. Several indicators of crop productivity and economic performance have been built. Given that for each of these two categories provided very similar results, we selected the two indicators that are believed to be the most related to the objectives of the AAS system in Senegal: crop yield (measured in kg/ha) and gross margin (measured in FCFA/ha) defined as the difference between the total value of production per hectare minus costs incurred (seed, fertilizer, pesticides, off-farm labor costs, and "others" costs). Output and input prices were directly derived from the questionnaire. For the households that did not sell (buy) any unit of a given output (input), we use the district-level median price. Table 1 reports the descriptive statistics for the four main crops of the crop-level variables used in the study.[4] Crop area, improved seed, traditional seed, fertilizer use, and hired labor are the explanatory crop-level variables used to explain crop yield and gross margin. We observe that the participants to the AAS system cultivate slightly more millet and paddy, and use more improved seeds and fertilizer. The higher use of improved seeds and fertilizer may be at least partially related to the fact that farmers that access to AAS tend to be recipients of subsidized inputs too (see below). The participants to the AAS system have also higher yields on corn, paddy, and groundnut. They also have higher gross margins for these crops but the difference is smaller than for yields.

Table 2 provides the descriptive statistics of the variable of interest "access to AAS" and we see that 17% of the households in the sample have access to AAS. The dataset contains more detail on the nature of AAS (not shown in the table). 97% of those who have access to AAS have received at least one visit from an extension agent, but the information on the exact number of visits is not available. For 93% of the AAS recipients, the advice mainly focused on agricultural practices while for the rest of the recipients the focus was mainly on the processing of crops, grain marketing, or other aspects of farming. We did not discriminate the analysis according to the type of advice

[4]The other crops included in the study—that represent 35% of the sample—are sorghum, cowpea, sesame, cassava, potato, onion, tomato, cabbage, watermelon, eggplant, okra, sorrel, carrot, and chilli plant.

TABLE 1 Definition, descriptive statistics of the crop-level variables used in the regressions.

Variable	Definition	Crop	Overall	Participants	Nonparticipants	Diff
Crop area	Area of the planted crop (hectare)	Millet (*n* = 2071)	2.26 (1.87)	2.72 (1.89)	2.22 (1.86)	0.49*
		Corn (*n* = 1405)	1.38 (1.36)	1.4 (1.65)	1.38 (1.3)	0.02
		Paddy (*n* = 1489)	1.18 (1.91)	1.34 (2.32)	1.09 (1.45)	0.25**
		Groundnut (*n* = 2546)	2.35 (2.31)	2.58 (2.61)	2.32 (2.21)	0.26
Improved seed	Amount of improved seed used (kilo/hectare)	Millet	0.23 (1.33)	0.9 (2.05)	0.17 (1.20)	0.73**
		Corn	1.61 (3.67)	2.4 (4.86)	1.49 (3.47)	0.92
		Paddy	47.21 (43.28)	59.28 (40.8)	40.45 (53.67)	18.83*
		Groundnut	4.94 (10.94)	8.16 (14.96)	4.57 (10.33)	3.59**
Traditional seed	Amount of traditional seed used (kilo/hectare)	Millet	6.94 (7.29)	4.9 (6.98)	6.03 (7.31)	−1.12***
		Corn	19.16 (13.32)	22.81 (17.09)	18.58 (12.53)	4.23*
		Paddy	42.58 (54.72)	32.1 (54.7)	48.46 (53.88)	−16.36*
		Groundnut	67.45 (37.56)	62.59 (38.5)	68 (37.43)	−5.42**
Fertilizer use	Amount of fertilizer used (kilo/ hectare)	Millet	19.59 (24.71)	27.44 (26.31)	18.97 (22.36)	8.47**
		Corn	64.89 (50.07)	88.98 (54.45)	61.08 (47.11)	27.91*
		Paddy	266.36 (233.19)	363.44 (219.23)	211.92 (238.3)	151.51*
		Groundnut	20.44 (44.61)	27.54 (44.92)	19.64 (44.52)	7.90*
Hired labor	= 1 if off-farm labor has been hired	Millet	.04 (0.19)	0.09 (0.29)	0.03 (0.18)	0.06**
		Corn	0.05 (0.21)	0.08 (0.25)	0.04 (0.2)	0.04***
		Paddy	0.1 (0.3)	0.14 (0.35)	0.08 (0.27)	0.07*
		Groundnut	0.04 (0.19)	0.05 (0.21)	.04 (0.18)	0.01
Log (yield)	Log of the yield (kg/ha)	Millet	5.97 (0.6)	5.99 (0.6)	5.97 (0.6)	0.03
		Corn	6.24 (0.79)	6.61 (0.72)	6.18 (0.80)	0.44*
		Paddy	7.6 (0.91)	8.05 (0.82)	7.34 (0.93)	0.72*
		Groundnut	6.23 (0.67)	6.33 (0.67)	6.22 (0.67)	0.12*
Log (gross margin)	Log of the gross margin (FCFA/ha)	Millet	14.33 (0.06)	14.34 (0.06)	14.32 (0.06)	0.01
		Corn	14.35 (0.08)	14.37 (0.08)	14.35 (0.07)	0.02*
		Paddy	14.43 (0.15)	14.49 (0.16)	14.40 (0.13)	0.09*
		Groundnut	14.36 (0.11)	14.37 (0.11)	14.35 (0.10)	0.02***

Abbreviation: PAPA, Projet d'Appui aux Politiques Agricoles.

*$p < 0.01$; **$p < 0.05$; ***$p < 0.1$ (t tests used).

Source: Authors' calculations from PAPA survey (2017).

TABLE 2 Definition and descriptive statistics of the household-level variables used in the regressions.

Variable	Definition	Overall	Participants (*n* = 974)	Nonparticipants (*n* = 4759)	Diff. in means
Household-level variables					
Extension	= 1 if received advices from advisory services during the season	0.17 (0.35)	n/a	n/a	n/a
Fertilizer subs	= 1 if received fertilizer subsidies (subsidized)	0.23 (0.42)	0.52 (0.5)	0.17 (0.38)	0.35*
OP	= 1 if member of a producer organization	0.19 (0.39)	.45 (0.5)	0.13 (0.34)	0.32*
Credit	= 1 if the household take out a loan	0.07 (0.25)	0.12 (0.32)	0.06 (0.23)	0.06*
Female	= 1 if female headed household	0.07 (0.25)	0.07 (0.25)	0.07 (0.26)	0.00
Age	Age of the household head	52.2 (13.2)	53.0 (12.3)	52.05 (13.48)	1.02**
AME	Adult male equivalent	7.45 (3.88)	7.3 (3.92)	7.48 (3.87)	−0.18
Dependency	Total dependency ratio[a]	1.00 (0.84)	1.01 (0.91)	1.02 (0.83)	−0.01
Literacy	% of literate in the household	0.22 (0.25)	0.24 (0.23)	0.22 (0.25)	0.02*
Wealth index	Index of wealth[b]	2.51 (1.78)	2.82 (1.81)	2.44 (1.77)	0.38*
Specialization	Share of the total household income coming from agriculture (crop)	0.79 (0.36)	0.78 (0.37)	0.8 (0.36)	−0.02
Cattle	= 1 if the household own cattle	0.30 (0.45)	0.32 (0.47)	0.29 (0.45)	0.03**
Farm area	Total area cultivated (in ha)	3.24 (3.92)	2.76 (4.08)	3.33 (3.89)	
Off-farm income	= 1 if the household has off-farm income	0.33 (0.47)	0.37 (0.48)	0.32 (0.47)	0.05*
Instrument	% farmers receiving advice in the community, minus the respondent	0.16 (0.24)	0.45 (0.29)	0.08 (0.15)	0.37*

Abbreviation: n/a, not applicable.

Note: SD in parenthesis. For each of six items, the household gets the value of 1 if it owns/uses the most sophisticated technology/service. Those items are: water source, toilet type, energy consumed to produce light, roofing material, wall type, and house floor type. *$p < 0.01$, **$p < 0.05$ (*t*-tests used for continuous variables and χ^2 test for binary variables).

[a]Number of young and elderly people over the number of people of working age.

[b]The index is a count variable.

received because even if a recipient declared that the "main" support received was on aspects not related to agricultural practices, it is actually impossible to state that advice on production was not dispensed.[5] Eighty-three percent of the recipients benefited from AAS issued by the public sector. We were not able to make a distinction according to the origin of the AAS (public or private) because of the large share of the recipients in the sample that

[5]We run the models were these 7% of households that received the main advices on nontechnical aspects and were classified as nonrecipients of AAS. It does not lead to any qualitative change in terms of signs and significance of the coefficients.

have actually access to the public AAS system and because the nonpublic AAS cover unclear AAS providers in the questionnaire such as "projects" and "programs" that may still be (partially) funded by the public sector. Finally, most of the recipients (93%) declared that they were satisfied with the AAS received. Given this information, the impact of the AAS assessed in this study correspond to the conventional public AAS system that focus on agricultural practices and implemented through at least one visit from an extensionist on the farms. Table 2 also presents the descriptive statistics of the household-level explanatory variables used in the study that are expected to have an effect on participation to the AAS system and on the outcome variables. A first set of variables refers to the farmer and household characteristics: age and gender (female) of the head of the household, and the level of literacy, size (adult male equivalent [AME]) and composition (dependency) of the household. The second set includes economic and financial variables: a household wealth index, and dummy variables whether the household receives off-farm income and contracted a credit. The third category gather farm characteristics: the level of specialization of the farm into crop production and whether cattle is raised on the farm. Lastly, the dummies Fertilizer subs and PO allow taking into account if the household is recipient of the input subsidy program and if he is a member of a PO. We observe that recipients of AAS have rather similar farmer, household, and farm characteristics than nonrecipients. Differences actually appear on the other variables. The recipients have a higher wealth index and a higher likelihood to have off-farm income and access to formal credit. About half of them are PO members and are recipients of subsidized fertilizer, whereas the percentage drop to about 15% for the nonrecipients of AAS.

5 | RESULTS

5.1 | Probit estimation results

Table 3 shows the marginal effects of the Probit regressions for access to AAS. They correspond to the first step results of the CF and identify the determinants of farmer access to AAS. For the sake of comparison, we also report the marginal effects when the model is run at the household level and we observe very similar results.

As mentioned in Section 3, the instrument is highly significant and is strongly associated with the actual participation in AAS. The results also show that being a member of a PO influences access of farmers to AAS positively by 8%. This result can be expected as PO frequently contact ANCAR to dispense specific AAS to their members (Franzel et al., 2018). Likewise, receiving an input subsidy also enhances the likelihood of accessing agricultural advice by 2%, confirming the relevance of accounting for a possible joint access to subsidized inputs and AAS (Ragasa & Mazunda, 2018). The positive impacts of the wealth index, off-farm income, and crop area indicate that the most endowed farms are those that have easier access to AAS. In addition, the estimates show that access to AAS is positively related to the age of the household's head, share of dependents in the household, and the use of fertilizer.

5.2 | Impact of access to AAS on input uptake and farm performance

Table 4 report the results of accessing AAS on input use and farm performance. The lower part of the table shows that the generalized residuals from the CF models are significant for the fertilizer uptake and yield equations. It indicates that unobserved factors influencing the access to AAS also affect fertilizer uptake and yields, confirming the need to account for the selection bias. The negative signs suggest a positive selection bias, meaning that farmers with above than average fertilizer use and yield level are more likely to access to AAS.

Estimates show that accessing AAS increases the probability to use improved seeds by 5% while the impact on fertilizer is nonsignificant. Interestingly, when the variable on whether the farmer received fertilizer subsidies (Fertilizer subs) is not included in the estimation, access to AAS on fertilizer use becomes significantly positive

TABLE 3 Probit estimation explaining the access to extension services.

	Crop level	Household level
Instrument	0.524* (0.000)	0.533* (0.000)
Fertilizer subs	0.022** (0.024)	0.041* (0.000)
OP	0.079* (0.000)	0.081* (0.000)
Credit	0.003 (0.857)	−0.002 (0.867)
Female	−0.009 (0.524)	−0.015 (0.292)
Age	0.001*** (0.082)	0.001** (0.036)
Literacy	0.030 (0.125)	0.011 (0.514)
AME	−0.000 (0.799)	−0.000 (0.819)
Dependency	0.010*** (0.072)	0.008 (0.102)
Wealth index	0.009* (0.002)	0.011* (0.000)
Specialization	0.012 (0.336)	0.014 (0.281)
Cattle	0.014 (0.155)	0.009 (0.309)
Off-farm income	0.021** (0.032)	0.023** (0.016)
Crop area[a]	0.009* (0.003)	0.005** (0.014)
Traditional seed	−0.000 (0.261)	
Improved seed	−0.000 (0.316)	
Fertilizer use	0.00005** (0.021)	
Hired labor	−0.015 (0.177)	
Crop dummies	Yes	No
Seasonal dummies	Yes	No
District dummies	Yes	Yes
Observations	11,794	5733
Pseudo R^2	0.38	0.40
Wald F-stat (instrument)	489.05	626.35

Note: The table displays the marginal effects with p values in parenthesis. SEs are clustered at farm level.
Abbreviation: AME, adult male equivalent.
[a]Crop area is the farm area for the household model.
*$p < 0.01$; **$p < 0.05$; ***$p < 0.1$.

(not shown in the table). It confirms the finding of Ragasa and Mazunda (2018) that we may account for input subsidy when we estimate the impact of the AAS system on agricultural practices and productivity.

Access to AAS has a significant and positive effect on both yield (24%) and, to a lesser extent, gross margin (1.6%). The IV-2SLS and CF procedures provides similar estimates, showing that the probit model form the selection equation is correctly specified (Wooldridge, 2015). It should be kept in mind that this treatment effect values are upper limits rather than average impacts because the dependent variables use the logarithmic function (Bellemare, 2012). Hence, the impact of access to AAS on economic performance (gross margin) can be considered as very weak. The positive result on crop yield is consistent with related studies carried out in SSA. Nakano et al.

TABLE 4 Estimates of the impact of access to extension services on input uptake and farm performance indicators.

	Improved seeds		Fertilizer		Log (yield)		Log (gross margin)	
	IV-2SLS	CF	IV-2SLS	CF	IV-2SLS	CF	IV-2SLS	CF
Extension	0.059* (0.000)	0.053* (0.000)	0.002 (0.915)	−0.025 (0.251)	0.237* (0.000)	0.251* (0.000)	0.016** (0.079)	0.016** (0.059)
Fertilizer subs	0.073* (0.000)	0.073* (0.000)	0.607* (0.000)	0.609* (0.000)	0.128* (0.000)	0.127* (0.000)	0.027* (0.001)	0.027* (0.001)
OP	0.034* (0.001)	0.035* (0.000)	0.020** (0.055)	0.024*** (0.028)	−0.046** (0.057)	−0.048*** (0.045)	−0.009 (0.368)	−0.009 (0.367)
Credit	0.037* (0.005)	0.037* (0.005)	−0.004 (0.747)	−0.005 (0.735)	0.001 (0.970)	0.001 (0.966)	−0.002 (0.906)	−0.002 (0.906)
Female	−0.014 (0.263)	−0.014 (0.261)	−0.005 (0.694)	−0.005 (0.657)	−0.139* (0.000)	−0.138* (0.000)	−0.012 (0.216)	−0.012 (0.220)
Age	0.001 (0.376)	0.001 (0.370)	−0.004* (0.004)	−0.004* (0.005)	−0.002 (0.543)	−0.002 (0.533)	−0.000 (0.721)	−0.000 (0.722)
Age squared	−0.000 (0.217)	−0.000 (0.213)	0.00003*** (0.010)	0.000*** (0.013)	0.000 (0.705)	0.000 (0.695)	0.000 (0.931)	0.000 (0.931)
Literacy	0.035*** (0.016)	0.036*** (0.015)	0.081* (0.000)	0.082* (0.000)	0.035 (0.391)	0.034 (0.402)	−0.015 (0.399)	−0.015 (0.400)
AME	−0.001 (0.330)	−0.001 (0.331)	0.000 (0.945)	0.000 (0.953)	0.003 (0.144)	0.003 (0.146)	−0.002*** (0.019)	−0.002*** (0.019)
Dependency	0.002 (0.590)	0.002 (0.576)	0.004 (0.286)	0.004 (0.252)	−0.015 (0.121)	−0.015 (0.129)	−0.005 (0.149)	−0.005 (0.148)
Wealth index	0.001 (0.677)	0.001 (0.661)	0.012* (0.000)	0.012* (0.000)	0.023* (0.000)	0.023* (0.000)	0.005* (0.004)	0.005* (0.004)
Specialization	−0.001 (0.957)	−0.001 (0.959)	−0.005 (0.618)	−0.005 (0.631)	0.303*** (0.016)	0.303*** (0.019)	0.056*** (0.032)	0.056*** (0.031)
Cattle	0.003 (0.707)	0.003 (0.693)	0.013** (0.081)	0.013** (0.069)	0.074* (0.004)	0.073* (0.004)	0.016*** (0.030)	0.016*** (0.031)
Off-farm income	−0.011 (0.152)	−0.011 (0.162)	−0.014** (0.068)	−0.014** (0.082)	0.065 (0.131)	0.065 (0.142)	0.019** (0.069)	0.019** (0.069)
Crop area	0.016* (0.000)	0.016* (0.000)	0.035* (0.000)	0.035* (0.000)	−0.086* (0.000)	−0.086* (0.000)	−0.016* (0.000)	−0.016* (0.000)
Crop area squared	−0.001*** (0.029)	−0.001*** (0.029)	−0.001* (0.000)	−0.001* (0.000)	0.004* (0.000)	0.004* (0.000)	0.001* (0.000)	0.001* (0.000)
Traditional seed					0.001* (0.000)	0.001* (0.000)	0.0004* (0.000)	0.0004* (0.000)
Improved seed					0.001* (0.000)	0.001* (0.000)	−0.000 (0.965)	−0.000 (0.966)
Fertilizer use					0.001* (0.000)	0.001* (0.000)	0.0002* (0.000)	0.0002* (0.000)
Hired labor					0.150* (0.000)	0.150* (0.000)	−0.019 (0.196)	−0.019 (0.197)
Generalized residual		−0.016 (0.173)		−0.018** (0.055)		−0.101* (0.001)		0.010 (0.339)

(Continues)

TABLE 4 (Continued)

	Improved seeds		Fertilizer		Log (yield)		Log (gross margin)	
	IV-2SLS	CF	IV-2SLS	CF	IV-2SLS	CF	IV-2SLS	CF
Intercept	0.071** (0.095)	0.071** (0.098)	0.247* (0.000)	0.246* (0.000)	5.727* (0.000)	5.728* (0.000)	14.240* (0.000)	14.240* (0.000)
Crop dum.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Seasonal dum.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
District dum.	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	11,794	11,794	11,794	11,794	11,794	11,794	11,794	11,794
Pseudo R^2	0.677	0.679	0.698	0.698	0.793	0.794	0.469	0.473
F-stat (instrument)	4177.0		4177.0		4177.0		4177.0	

Note: SEs clustered at farm level. *p* values in parenthesis.

Abbreviations: AME, adult male equivalent; CF, control function; IV-2SLS, instrumental variable–two-stage least squares.

$^{*}p < 0.01$; $^{**}p < 0.1$; $^{***}p < 0.05$.

(2018) found that agricultural training allowed paddy yield to increase from 3.1 to 5.3 tons per hectare (+70%) in Tanzania. Emmanuel et al. (2016) estimate an impact of AAS on paddy rice in Ghana of 15%. Bellemare (2010) assesses the impact of the number of visits made by a technical assistant (from a private processing firm) on yield of green vegetables in Madagascar and found that the elasticity of yield with respect to number of visits lies between 1.3 and 1.7. Elias et al. (2013) concluded that AAS increase farm productivity (value of the crop produced) in Ethiopia by 20%. Mango et al. (2015) found a positive impact of AAS on technical efficiency in Zimbabwe. In contrast, Ragasa and Mazunda (2018) did not find the AAS program had any effect in Malawi, which is explained by the authors by the lack of implementation of the public extension program and by the large diversity of sources of agricultural advice that rather lead to confusion and contradictory instructions.

Other factors affect significantly input uptake and farm performance. As expected, access to subsidized fertilizer, being member of a PO, and access to credit affect positively the likelihood to use improved seeds and fertilizer. The share of literate in the households, the wealth level (only for fertilizer) and the crop area affect positively their use too. Access to subsidized fertilizer, wealth level, specialization level into crop activities, and the presence of cattle on the farm are all associated with higher crop productivity and economic performance. The latter variable may be related to the production of manure from the cattle that improves fertilizer efficiency (Tounkara et al., 2020). A noninverse relationship between land size and performance is found, which is consistent with recent findings on the topic (Garzón-Delvaux et al., 2020). The use of traditional seeds and fertilizer are associated with higher yields and gross margins. Actually, a 1-kg increase of fertilizer leads to a yield increase of 0.1% and an increase in the gross margin of 0.02%. The quantity of improved seeds and the use of hired labor only impact yields. Their non-significance on gross margin may be due to large unit costs compared to production gains they provide.

5.3 | Estimation of heterogeneous impacts

The disaggregated estimates show that the effects are not uniform across crops and the use of fertilizer (Table 5). AAS seems to procure positive impacts on the rainfed cereals yields (by +25%) and irrigated rice (by +12%), and in a lesser extent on their gross margin (about 2% for rainfed cereals and 4% for irrigated rice). Conversely, we found no consistent impact of access to AAS on yield and gross margin for legumes and horticultural crops. Access to AAS also impacts farmers who do not use fertilizer but has no impact on the other farmers.

6 | DISCUSSION AND POLICY IMPLICATIONS

This study presents evidence from Senegal concerning whether access to AAS results in input uptake changes and increasing crop yields and gross margins. The analysis is based on a nationally-representative household survey data collected in 2017. Two econometric methods are used to ensure a robust estimation of the impact while accounting for selection bias. We find moderate but positive impact of access to AAS on improved seed adoption, crop yield, and, in a lower extent, on gross margin. Results give an impact on improved seed uptake of 6%, on crop yield of 24%, and on gross margin of 2%. The positive impact on cereal yields may explain why in our sample, 93% of the participants to the AAS system declared to be satisfied with the AAS received. Yet, if the access to AAS seems to increase crop yield, the effect on gross margin is very weak. It means that there is a room to improve agricultural advices that contribute to enhance both yields and farmers' income. AAS system should emphasize different aspects of farm performance so as to not only focus on the productive dimension. Yet, these results support the idea that the AAS systems in sub-Saharan Africa have an important role to play to contribute to enhance agricultural production, farmers' income and wellbeing. In Senegal, one of the challenges is to extend access to AAS system to a

TABLE 5 Estimates of heterogeneous impacts of access to extension services by crop type and fertilizer use.

		Log (yield)	Log (gross margin)
Rainfed cereals (*N* = 4107)	IV-2SLS	0.23** (0.02)	0.015** (0.02)
	CF	0.29*** (0.00)	0.021*** (0.00)
Irrigated rice (*N* = 1489)	IV-2SLS	0.131** (0.02)	0.039** (0.00)
	CF	0.109** (0.04)	0.036*** (0.00)
Legumes (*N* = 3341)	IV-2SLS	0.053 (0.27)	0.09 (0.12)
	CF	0.053 (0.29)	0.09 (0.13)
Horticultural crops (*N* = 1654)	IV-2SLS	0.021 (0.92)	0.074 (0.70)
	CF	0.138 (0.27)	0.170 (0.12)
Low fertilizer use (*N* = 6331)	IV-2SLS	0.296*** (0.00)	0.044*** (0.00)
	CF	0.347*** (0.00)	0.045*** (0.00)
High fertilizer use (*N* = 5388)	IV-2SLS	0.094 (0.24)	0.112 (0.11)
	CF	−0.032 (0.24)	−0.010 (0.68)

Note: **$p < 0.05$, ***$p < 0.01$ SEs clustered at farm level. *p* values in parenthesis. All specifications include district, seasonal, and crop dummies.

Abbreviations: CF, control function; IV-2SLS, instrumental variable–two-stage least squares.

larger share of farmers, without deteriorating the positive impacts on production and the level of household's satisfaction.

Several disaggregated models were also estimated to get a nuanced understanding of the impact of AAS. We find yield increases for cereals (rainfed and irrigated) but not for legumes and horticultural crops. This is rather counterintuitive, because cereals (and legumes) are crops cultivated in the country for long time so that a greater knowledge gap between extension agents and farmers is expected on horticultural crops. Yet, irrigated rice producers (located in the north,) are recipients of AAS through both the national (ANCAR) and regional (SAED) public agencies. The latter agency is a strong agricultural organization in the north of the country which significantly contributes to the implementation of AAS on irrigated rice. Furthermore, horticultural farmers (mainly located on the coastal area) have another source of access to inputs and advices, through contracts with traders who in exchange sell their products at agreed prices. Inputs are usually paid after selling the production. Therefore, access to advisory services might only bring marginal benefits compared to benefits from contracting production. It means that in regions (such as the Niayes) where farmers are specialized in horticultural crops, the appropriateness and relevance of advices on horticultural cultivation need to be revised. This is especially the case for the production of tomatoes where despite the support of the ANCAR extension agents, there is still limited pest management in fighting bacteriosis. It is also observed that access to AAS only impacts the performance of farmers who do not use fertilizer. This result suggests that to improve the AAS system's effectiveness, it would be usefull to provide farmers trainings to make a better use of fertilizer. Overall, results indicate the relevance to tailor the intervention and the provision of AAS to specific production orientation and current agricultural practices.

Finally, we acknowledge a main limitation to our study. Although it is known that the main theme in the advice received by farmers focused on production, provided by the public AAS system through visits to the farm, little is known on the exact practices promoted by the AAS system and the extension approach experienced by the recipients of AAS. Given the diversity of approach used by ANCAR and the other public AAS agencies, a detailed impact assessment accounting for the exact techniques promoted and the diversity of the AAS system in Senegal would be extremely valuable to better assess and enhance the relevance of the Senegal's AAS system. But for that purpose, there is a need to drastically improve the nature of the information available on the AAS in Senegal.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions. The original dataset can be available upon request to astou.dia@isra.sn.

ETHIC STATEMENT

Not applicable.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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