Good shit? Household effects of ecological sanitation in Mali.

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Abstract

Apart from providing adequate sanitation, ecological sanitation (EcoSan) aims at recycling nutrients by providing human fertilizer. For farming households, this fertilizer may act as a substitute for artificial fertilizers (improving the household budget) or as a complement (improving soil quality, increasing agricultural yields). Using household data from Mali, we do not find any support for human fertilizer being used complementary. Instead, we find that households with an EcoSan solution substitute artificial fertilizer with human fertilizer. While our results imply small economic household incentives for investing in EcoSan, we argue that the relevant comparison when contemplating the construction of ecological dry toilets is not the status quo of inadequate latrines or open defecation but rather investments in other sanitary solutions. The scope for ecological sanitation will hence be larger when there are no other forms of sanitation already in place.

Keywords: Ecological Sanitation, Evaluation, Fertilizer use, Household Productivity, Mali, Matching

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Introduction

The subject of human excretion and sanitation is still taboo to varying degrees in big parts of the world. However, lack of proper sanitation spreads diseases and kills millions of people every year. The fact that this is not a prioritized problem is worsening the situation. Ecological sanitation (EcoSan) is a general expression for sanitation systems aiming at creating adequate sanitation while at the same time recycling nutrients in order to reduce the need of artificial fertilizer (see Langergraber and Muellegger, 2005, for a general introduction into principles and concepts of EcoSan). The three major nutrient components of artificial fertilizer are nitrogen (N), phosphorus (P) and potassium (K) which all are taken up by plants and later eaten by humans, both through vegetal and animal food-stuffs. The same amounts of these nutrients that are consumed are also excreted, except for a small percentage that is absorbed by the human body while muscles and bones are still growing during childhood. This means that, in addition to the health effects of adequate sanitation, there is a potential direct economic gain through savings on artificial fertilizers (using human fertilizer as a substitute) or through increased returns to farming (using human fertilizer complementary). This may impact on farmers propensity to install facilities and somewhat brake the taboo related to the subject. Hence, EcoSan facilities in places where people lack proper sanitation and are engaged in agriculture have the possibility of addressing both a health dimension (absence of sanitation) and an economic dimension (soil depletion, return to farming).

With respect to the challenges of soil depletion and sanitation, Ecological sanitation has been studied surprisingly little from an economic perspective. Guzha et al. (2005) find a positive effect on maize production when exhausted soils are restored by sanitised human excreta. Schuen et al. (2009) compare the economic viability of EcoSan with conventional sanitation systems using case studies from three countries (Burkina Faso, South Africa and Uganda), concluding that a scaling-up of EcoSan is unlikely without considerable external support. The World Bank (2008) studies the socio-economic importance of sanitation in four Asian countries (Cambodia, Indonesia, the Philippines and Vietnam) and finds very important economic effects of investments in sanitation at the country-wide level. Economic losses resulting from poor sanitation average 2 per cent of GDP of which the largest part concerns health effects. While there is no research known to us that explicitly studies the health effects of EcoSan, Niwagaba et al. (2009) and Nordin et al. (2009) note the importance of accurate treatment of faeces in order to avoid diseases and to assure that the sanitation process produces safe fertilizers. Maybe unsurprisingly, the literature on the relation between sanitation in general and health tend to find that a sanitary disposal of excreta has positive health effects (see Waddington et al., 2009, for a review of the literature on various interventions to reduce diarrhoea).

In this study, we evaluate an EcoSan project in Mali, run by the organisation CREPA (Centre Régional pour l'Eau Potable et l'Assainissement à faible coût), where just over 150 beneficiaries got a urine diverting dry toilet (UDDT) installed, making possible the use of excreta as fertilizer.[1] In Mali, only 22 per cent of the households are estimated to use adequate sanitation facilities and 14 per cent practice open defecation, which means that they depend on buckets, bushes, the banks of a stream or other sheltered places for their several daily excretions (WHO/UNICEF, 2012). For families in rural Mali who are engaged in small size farming that just about cover the family food demand, buying fertilizer is expensive. Often they use no or too little fertilizer so that insufficient amounts of nutrients are added to the soil, resulting in soil depletion of nutrients, which leads to decreasing yields.

[1] The investments took place in the municipality Guégnéka, consisting of the small town of Fana and its surroundings in the region of Koulikoro.

The EcoSan facilities studied in this project are built in small separate buildings at the household level. They separate the faecal matter from the urine and lead them to separate containers. The products are contained and sanitised for some time and then recycled (using, by turns, two separate pits for the faecal matter). The urine is led into plastic containers that are being replaced as they are filled. After a month's storage the urine is sanitised and can be used as fertilizer while faeces need to be stored for 6-8 months.

The UDDTs were constructed between March 2006 and May 2009, implying that, at the time of household interviews, they had been in place for between 60 and 22 months. Of the 155 dry toilets, the vast majority (104, or 67 per cent) was constructed in 2007, 18 in 2006, 28 in 2008 and 5 in 2009. The fact that we are studying a project that was implemented some years ago has both pros and cons. The obvious disadvantage is that other things may have happened during the post-construction period making potential effects influenced by other factors than the treatment. However, in addition to the fact that the use of EcoSan is to some extent a permanent treatment, an advantage to study a "settled" programme is that we may capture more permanent effects of EcoSan rather than potential initial effects that may fade away after some time (cf. the two cases in Banerjee et al., 2007, where initial large programme effects vanished over time). Indeed, the fact that five beneficiaries are no longer active in agriculture and that two other households, for unknown reasons, destroyed their dry toilets may provide some evidence of this.

2 Methods

There is no baseline survey performed prior to the introduction of EcoSan facilities, so we need to rely on methods using comparison groups. This is obviously more problematic given the time passed between implementation and evaluation of the programme. We face the typical problem of identifying a suitable comparison group of non-EcoSan users to answer the counterfactuals: What would the yield per hectare have been had the EcoSan users not used EcoSan? How high would the usage of artificial fertilizer have been had the EcoSan users not used EcoSan? Hence, we want to compare the outcome measures of targeted households to a relevant comparison group. One major problem is that farmers that invest in EcoSan self-select into this treatment implying that simple comparisons of the outcome between participants and nonparticipants yield biased estimates of the impact of EcoSan.[2] There is clearly an explicit self-selection into treatment where unobserved factors such as ability and effort determine whether a household apply for a UDDT or not. The factors determining selection by the village councils probably also include a number of unobservables. We cannot control for such factors.[3]

Our interest lies in estimating whether treated households did improve their performance in one of more dimensions in response to treatment.[4] Our method of estimation is so-called propensity score matching (PSM). The seminal work on PSM was done primarily by Paul R. Rosenbaum and Donald

[2] Potential sources of this bias could be that households that face an EcoSan project have some specific characteristics (selection on observables and/or unobservables) or that village non-participants gain from the existence of the programme (spill-overs), implying that the programme impact is underestimated.

[3] By including control households from another municipality in which CREPA has no engagement of any kind (Kéréla) we believe to somewhat decrease the influence from unobservables.

[4] Knowing that we have a number of non-compliers, that is, a number of households that are not using the output from the UDDT in farming, we estimate the average intention to treat (AIT).

B. Rubin in the 1970's and 1980's. Two overviews often referred to are Dehejia and Wahba (2002) and Todd (2008). We attempt to balance the group of beneficiaries and the control group using the propensity scores from a logit model of the probability to obtain a UDDT. We then compare the potential outcomes $Y_i(EcoSan)$ and $Y_i(NotEcoSan)$ where $Y_i(EcoSan)$ is the outcome of a household having a UDDT and $Y_i(NotEcoSan)$ is the outcome of the same household not having a UDDT. We are interested in the effect $E[Y_i(EcoSan)-Y_i(NotEcoSan)|EcoSan]$, i.e. the difference between the observed outcome of a household having a UDDT and the missing counterfactual, i.e. the potential outcome for the same household had it not had EcoSan, for which we use the outcome of matched controls. As is more or less standard in the literature, we apply a quite large number of different matching methods in order to provide a range of the effects rather than one single point estimate.

Our outcomes of interest concern household yields as well as the use of fertilizers. We use two outcome measures for yields; the average (local) market value of yield per hectare, calculated as the total market value of each household's harvest divided by the total area of cultivated land; and the number of months the respondent claims that the household can feed itself with the harvest. If human fertilizer simply replaces artificial fertilizers, we do not expect to find any substantial effect for those two outcomes. We therefore also estimate the effect on the total amount of chemical fertilizer utilized (in terms of quantity and expenditures) as well as the quantity of specific fertilizers used.

Our household data was collected between March 24 and April 24, 2011. The list of beneficiaries includes 180 localities of which 17 belong to schools, markets and mosques. We were able to interview 155 of the remaining 163 households. Five (urban) beneficiaries were not engaged in farming.[5] These five households were dropped from our data. 40 of the remaining 150 beneficiary households reside in the urban area Fana and 110 live in the surrounding rural villages. Control households were selected in collaboration with CREPA trying to find households meeting the eligibility criteria for a dry toilet. We interviewed 97 control households in Fana and 135 households in the surrounding villages. Two rural and one urban household were not active in agriculture and were hence dropped. In addition, we performed 231 interviews with (rural) households from another municipality in which CREPA has no engagement of any kind (Kéréla). This gives us 610 interviews in total (150 beneficiaries and 460 controls).

Our questionnaire provides data on the amounts of artificial fertilizer used, EcoSan fertilizer used, the costs of fertilizer and EcoSan facilities, the area of cultivation, the yields of the cultivation and a number of household indicators. Summary statistics for group of treated and controls are found in Table 1. Among other group differences, we note that treated households on average are larger, consist of more females, have some education to a larger extent, are wealthier and lives closer to their fields.[6]

Table 1. Summary statistics, treated (N=150) and controls (N=460)

	Treat	Controls	Difference	S.E.	P-value
Household members	14.580	13.798	-0.782*	-0.434	0.072
Age over 55, share	0.434	0.480	0.046**	-0.019	0.018

[5] 4 did not own any land and one did not cultivate the 1 ha owned. Their UDDTs were erected during March-July 2007.

[6] Our asset data closely resembles those collected in the World Banks Demographic Health Surveys (DHS) which are regularly summarized by an index of socio-economic position constructed from a principal components analysis (see Rutstein and Johnson, 2004 and Vyas and Kumaranayake, 2006). We follow that methodology when constructing the wealth index.

Females, share	0.459	0.431	-0.029**	-0.012	0.018
Has any education, share	0.439	0.385	-0.054**	-0.022	0.013
Works on fields, share	0.459	0.500	0.042*	-0.021	0.052
Have own income, share	0.143	0.141	-0.002	-0.014	0.905
Severely ill last season, share	0.048	0.051	0.003	-0.008	0.664
Household head over 55	0.659	0.489	-0.170***	-0.046	0.000
Household head education	0.219	0.181	-0.038	-0.037	0.294
Tapped water	0.360	0.280	-0.080*	-0.043	0.065
Wealth index	0.357	-0.116	-0.474**	-0.199	0.017
Urban	0.267	0.209	-0.058	-0.039	0.139
Size cultivated land (ha)	9.980	10.704	0.723	-0.691	0.296
Distance field less 2km	0.340	0.230	-0.110***	-0.041	0.008
Distance 2-5km	0.153	0.157	0.003	-0.034	0.926
Distance over 5km	0.093	0.174	0.081**	-0.034	0.018
No crops cultivated	3.487	3.789	0.302**	-0.129	0.020
Use compost	0.873	0.804	-0.069*	-0.036	0.056
Millet	0.627	0.709	0.082*	-0.043	0.060
Maize	0.767	0.857	0.090**	-0.035	0.010
Haricots	0.227	0.207	-0.020	-0.038	0.601
Cotton	0.433	0.530	0.097**	-0.047	0.039
Average yields (CAF*1000)	109.412	113.918	4.506	-6.872	0.512
Feedmonths	8.698	8.637	-0.061	-0.278	0.826
Art. Fert. (Expenditures, CAF*1000)	101.359	107.116	5.757	-16.375	0.725
Art. Fert. (50k)	7.145	8.819	1.674	-1.070	0.118
Complexe coton (50k)	3.960	4.960	1.000	-0.624	0.110
Complexe céréale (50k)	0.840	0.417	-0.422**	-0.202	0.037
Urea (50k)	2.345	3.451	1.106**	-0.442	0.013

Notes: Averages for the treated and control groups together with group differences and test results for equality of means (t-test) with significance at the 10 (*), 5 (**) or 1 (***) per cent levels. Control variables are interpolated.

Table 2 presents some statistics for the sample of beneficiaries. First, note that the rate of compliers is 70 per cent of the designated beneficiaries, i.e. 105 out of 150 households report to have used human fertilizer in agriculture. The average size of land fertilized with human fertilizer is 2 hectares. The vast majority, almost 90 per cent, applies the fertilizer by putting the sanitised excrements on the compost; a few households (14 per cent) use the fertilizer directly on the fields during the dry season and a fourth use the fertilizer directly on fields during the rains. A third of the beneficiaries use urine only, two households report to use only faeces, and around 37 per cent uses both urine and faeces. Of the 103 compliers that report to use urine in agriculture, only 46 households have an idea of the quantity applied, reporting an average of 205 litres, and of the 58 household using faeces, only 6 households report the quantity applied, averaging 134 kilograms. Finally, a large majority of beneficiaries report the UDDT to be economically profitable, to have reduced the incidence of diarrhoea, and to have led to less smell.[7]

[7] We should expect responses to the last questions to be biased. This is evidenced by 125 households reporting the UDDT to be economically profitable, which must be considered high given the 105 compliers.

Table 2. Summary statistics, treated sample

	N	mean	S.D.	min	max
Did use h.f. from the UDDT	150	0.700	0.46	0	1
Size cultivated land (ha)	150	9.980	7.296	0.050	40
Land fertilized w. h.f. (ha)	103	2.027	2.984	0.038	18
H.f. on compost	104	0.885	0.321	0	1
H.f. on land, dry season	104	0.135	0.343	0	1
H.f. on land, during rains	104	0.250	0.435	0	1
Urine only	149	0.315	0.466	0	1
Faeces only	149	0.013	0.115	0	1
Urine and faeces	149	0.376	0.486	0	1
Urine, litres	46	205.2	227.5	20	1200
Faeces, kg	6	133.8	82.030	53	280
EcoSan - profitable	132	0.947	0.225	0	1
EcoSan - less diarrhoea	127	0.984	0.125	0	1
EcoSan - less smell	134	0.821	0.385	0	1
EcoSan - more smell	134	0.157	0.365	0	1

Notes: H.f. means human fertilizer.

3 Results and Discussion

In order to arrive at our estimated treatment effects, we first need to estimate the propensity scores used in matching. Selection into the programme was made based on three eligibility criteria: (1) having own land to cultivate; (2) being at least 10 household members; (3) being able to contribute to the construction of the own dry toilet as well as to other dry toilets, for a period of six months, in cash or in kind through material or raw labour. Our selection of households for the control group was, in a weak fashion, based on the first two criteria.[8] Hence, we do not expect them to differ dramatically between groups, although we did not know the size of possessed land or the exact size of the households prior to interviews. We expect these eligibility criteria to also affect (at least some of) the outcome variables. This makes them good candidates for inclusion in estimation of the propensity score.[9] We estimated the propensity scores by including in our logit model all covariates that in a t-test differed significantly (using ten per cent as a, liberal, level of significance) between the treated and the control groups. In addition, we included covariates that we hypothesize are correlated with the outcome of interest: household size; the share of the household being between 16-54 years of age; the household share of females; the household share having any education; the household share working in the fields during the rains; the wealth index; the amount of artificial fertilizers used[10]; the number of crops cultivated; a dummy for Fana (urban); a dummy for whether the household has a compost or not; whether the household has tapped water or not; dummy for whether the household head is in the

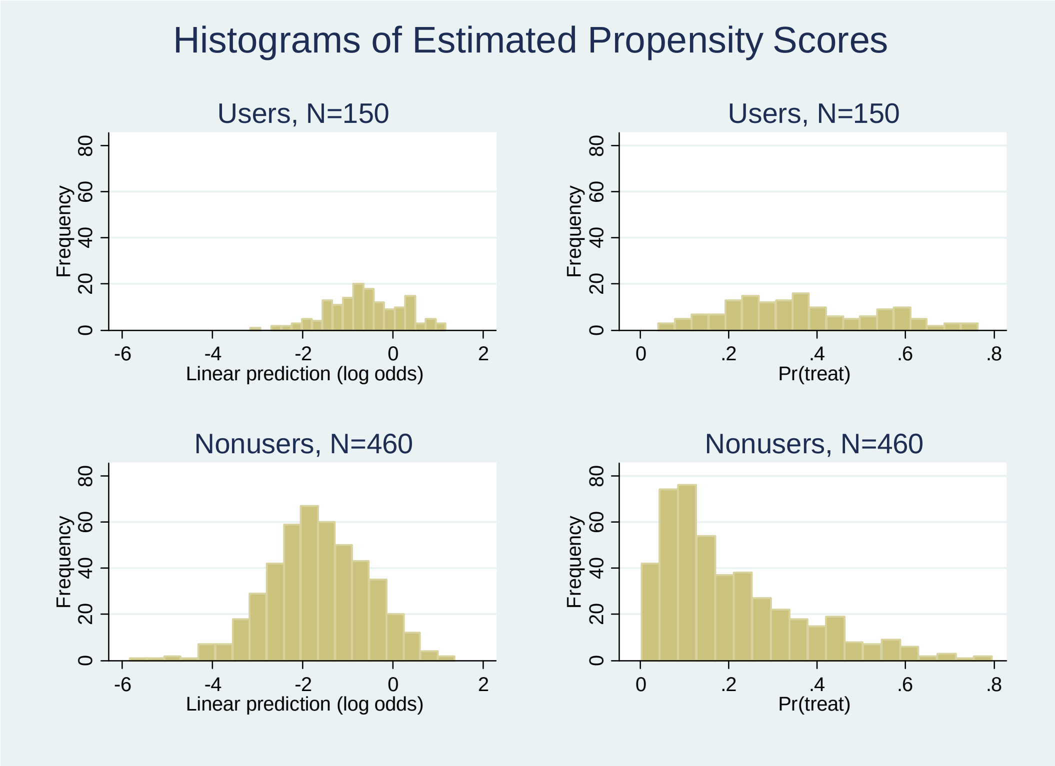
[8] I.e., since we started with the ”treated” group we did choose our controls based on these characteristics in order to make the control group as similar as possible to the treatment group. Therefore, we did not consider modelling the selection process explicitly. Also, since most families in the area are engaged in farming, the first constraint did probably not exclude many households a priori.

[9] For differing views on which covariates to include, see e.g. Imbens and Wooldridge (2009, page 50), (Fu and Li, 2008), Stuart (2010) and Clarke et al. (2011).

[10] When we use the amount of artificial fertilizers as an outcome, we re-estimate the propensity score without these variables.

age group 55 and older; and dummies for whether the household grows millet, maize, haricots or cotton.

Figure 1. Distribution of propensity scores



Apart from the decision of which covariates to include in the estimation of propensity score, one additional question is which statistic to use as the propensity score. While any monotone transformation is valid, the two main candidates are the estimated probability of treatment (used, for example, by Dehejia and Wahba, 2002) and the linear prediction (i.e. the log odds, or the logit, used, for example, by Rosenbaum and Rubin, 1985). Figure 1 graphs the propensity scores using, in turn, log odds and probabilities. The graph suggests that, regardless of propensity score used, there is a sufficient overlap in scores in order to focus our analysis on the common support. In the following, we use the linear prediction.[11]

Our findings from estimation are presented in Table 3. The first column (”TTEST”) gives the raw difference in mean between the full sample of treated and control households and indicate whether the

[11] Using probabilities instead of logits does not lead to any larger difference in results. Furthermore, since we have data for one point in time only, we face the risk, in particular when treatment is successful, that the outcome variable of interest has affected a number of potentially important covariates. If a successful use of human fertilizer implies increased yields, or lower expenditure on artificial fertilizer, a household may contemplate changing their fertility, schooling, or labour supply decisions, increase their ownership of durables, increase (or decrease) the use of fertilizer or change the composition of crops (however, whether assets are increased in response to increased income will depend on the extent to which farmers interpret the income increase as permanent or transitory, the latter will likely have a smaller impact on asset ownership). Including only a set of covariates that we believe are credibly exogenous did not change our results (results available from the authors).

means are significantly different from each other in a t-test. The second column (”OLS”) presents the coefficient for a treatment dummy in an OLS regression including as controls the same covariates used in estimation of the propensity scores. Columns 3 to 7 presents the treatment effect from five different matching estimators using the propensity score for balancing. These, in turn, are: one-to-one matching without replacement (column 3, ”M1to1NR”); one nearest neighbour caliper matching (with replacement) using a caliper width of 0.25 the standard deviation of the propensity score (column 4, ”M1to1CR”), five nearest neighbour caliper matching (with replacement) using a caliper width of 0.25 the standard deviation of the propensity score (column 5, ”M5to1CR”); kernel matching using the epanechnikov kernel (column 5, ”Kernel”) and local linear regression using the tricube kernel (column 7, ”LLR”).[12] All matching estimators use the common support only. Standard errors in columns 3 to 7 are bootstrapped using 50 replications.

Table 3. Treatment effects

	TTEST	OLS	M1to1NR	M1to1CR	M5to1CR	Kernel	LLR
Avg. yields	-4506	2132	-95.99	1490	1630	1442	99.08
	(6872)	(6720)	(8737)	(9791)	(8682)	(8919)	(8653)
N treat/ctrl	138/434	138/434	138/138	138/100	138/247	134/323	138/100
Feedmonths	0.0609	0.0684	-0.194	-0.180	0.0700	0.170	0.0960
	(0.278)	(0.262)	(0.393)	(0.412)	(0.379)	(0.330)	(0.273)
N treat/ctrl	139/449	139/449	139/139	139/100	139/251	135/343	139/100
Art. fert. (exp.)	-5757	-8770	-8903	571.7	-9475	-6202	-3100
	(16375)	(14447)	(22268)	(28838)	(21648)	(25873)	(24464)
N treat/ctrl	131/401	131/401	130/130	130/90	130/229	128/319	130/90
Art. fert. (50k)	-1.674	-1.852**	-1.639	-1.507	-2.240*	-2.153	-1.687
	(1.070)	(0.817)	(1.517)	(1.416)	(1.315)	(1.550)	(1.291)
N treat/ctrl	145/448	145/448	144/144	144/103	144/264	142/373	144/103
C. Coton (50k)	-0.946	-0.811*	-0.579	-0.828	-1.014	-0.979	-0.607
	(0.641)	(0.484)	(0.749)	(0.993)	(0.950)	(0.805)	(0.609)
N treat/ctrl	146/448	146/448	145/145	145/103	145/264	143/373	145/103
C. Céréale (50k)	0.418**	0.156	0.0486	0.306	0.0361	0.158	0.0366
	(0.207)	(0.209)	(0.331)	(0.396)	(0.329)	(0.235)	(0.247)
N treat/ctrl	145/449	145/449	144/144	144/103	144/265	142/374	144/103
Urea (50k)	-1.096**	-1.189***	-1.118**	-0.910	-1.154**	-1.253*	-1.055**
	0.455	0.379	0.508	0.739	0.565	0.723	0.474
N treat/ctrl	145/449	145/449	144/144	144/103	144/265	142/374	144/103

Notes: Treatment effects as described in text with bootstrapped standard errors in parenthesis (50 replications) and significance at the 10 (*), 5 (**) or 1 (***) per cent levels.

We focus our discussion on the consistency of the estimated treatment effects over column 3 to 7. First, we note that our overall measure of economic gains, the market value of per-hectare average yields (*Avg.yields*) never turns out significant and one estimate even suggest a negative effect on yields (column 3). The same absence of results is found for the self-reported number of months that the household is able to feed itself with the season’s harvest (*Feedmonths*). Turning to the use of fertilizers, results are somewhat less ambiguous. We use two aggregate measures for the use of artificial fertilizer; the self-reported total expenditure on fertilizers during last season (*Art.fert.(exp)*) and the number of sacks a 50 kilos of artificial fertilizer applied on the fields the last season (*Art.fert.(50 k)*, that is, the sum of Complexe Coton, Complexe Céréale, and Urea). We find no effect

[12] All estimations were made in Stata 12.1, using the package psmatch2.

on reported outlays on artificial fertilizers.[13] While the estimates for *Art.fert.(50 k)* are in general not statistically significant, they do suggest that beneficiaries used on average about one to two sacks less of artificial fertilizer during the season as compared to the control group. Looking at the specific types of fertilizer, the main reduction seems to be in the nitrogen rich fertilizer Urea, which is the only of the three fertilizers whose estimated effect is statistically significant.[14] In sum, our findings suggest that yields are largely unaffected by the state of being EcoSan beneficiary, but beneficiary households seem to use significantly less artificial fertilizers.

4 Conclusions

In large parts of the world, the lack of proper sanitation entails disastrous health effects which to a large extent could be prevented by available, context adapted, sanitation facilities. Bad sanitation is also wasteful. Human excrements contain the most important nutrients necessary for plants to grow and tend to end up in rivers, leading to eutrophication, instead of being used productively. Studying a project in Mali where we collected demographic, economic and farming data from 618 households, of which 155 benefitted from the construction of a so-called EcoSan dry toilet, we find that the use of human fertilizer have no effect on household wide agricultural productivity, though it seems to decrease the use of artificial fertilizers.

To the extent that the substitution of artificial fertilizers with human fertilizer does not affect soil quality and average yields (and this seems to be the case according to reported yields), the program imply savings for the average household of about 20-40 EUR per year (the price of a sack average about 20 EUR and the average household use, among households not using EcoSan, is about 9 sacks implying savings of around 10 to 20 per cent of average outlays on artificial fertilizers). However, soils in Mali are in general poor, so a substitution does not appear to be superior to addition of these nutrients, at least not in a longer perspective. Thus, the economic gains from EcoSan appear quite low to act as an incentive for investment. However, we do not account for health effects at the household or community level. Moreover, the relevant comparison when contemplating the construction of ecological dry toilets is probably not the status quo of inadequate latrines or open defecation but rather investments in other sanitary solutions. The scope for ecological sanitation will hence be larger when there are no other forms of sanitation already in place.

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[13] Note that the response rate on this question is lower than for the other indicators.

[14] The estimates for Complexe Céréale are economically and statistically negligible, reflecting that this fertilizer is scarcely used in our sample, the average being half a sack per household.

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