About efficiency of collective provision of NRM investments in Burkina Faso.

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Abstract
This paper presents an analysis of the importance of collective action for the realization of Natural Resource Management (NRM) investments and its effect on community-level efficiency in the provision of NRM investments. This study is based on survey data collected in 2002 in 78 villages of northeastern Burkina Faso. The general cooperative capacity of each community is first recovered for any type of collective activity and is then used to explain the probability of a community undertaking reforestation activities and/or stone bunds construction, as well as to explain the efficiency level in the realization of those investments. Empirical results show that greater cooperative capacity indeed increases the likelihood of NRM investments to be undertaken at the community level; however, greater cooperative capacity also appears to lead to inefficient provision of these public goods.

1. Introduction

The northeast of Burkina Faso is a dry region where crop and livestock activities are strongly integrated. In such systems, there is wide scope for collective action and cooperation to influence land use and allocation patterns between private cropland and common rangeland, and to promote investments and management of community resources. With current trends of population pressure and land degradation, households increasingly have greater incentives to actively manage their natural resources, but at the same time, transactions costs of doing so tend to increase, at least as the population grows.

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There is a wide range of activities that can be undertaken at the community level in order to enhance the productivity and resilience of the natural resource base. For instance, community members may invest in water-point construction and maintenance, make agro-forestry investments, engage in bush clearing, or invest in water harvesting and soil erosion control measures. Each technique, management tool, or activity, will be characterized by different collective action requirements, and will also be characterized by different structure of costs and benefits that will affect individual incentives to engage in collective action. For instance, soil erosion control techniques, such as the construction of stone bunds, generally entail collective labor for their construction, but can be constructed either on private cropland or common pastures. If constructed on common pastures, benefits are shared amongst those who use pasture resources, whereas if they are constructed on private cropland, the individual realizes private gains, though there there are usually spillover benefits to the community as a whole in terms of reduced soil erosion. At the same time, each community will have different capacities for undertaking collective action, irrespective of any particular activity, and this capacity will also affect the degree of successfulness in these activities. In turn, we hypothesize that the effectiveness with which these decisions are implemented will have a direct impact on both short-term profitability and long-term sustainability of alternative production activities.

Thus, our focus in this paper is on community's capacity to cooperate, on developing indicators of this capacity, and then using these indicators to examine the impact of cooperative capacity on the public goods investments decision; given data collected, we consider decisions to construct stone bunds, and in engaging in reforestation activities. However, to get a better idea of the "effectiveness" of collective action to engage in reforestation and/or stone bunds, we also consider a measure of the efficiency of participation by community members in these activities. We do so by using a stochastic frontier estimation of reforestation and stone bund construction, and then determining which factors, including cooperative capacity, affect the level of efficiency in the provision of these investments.

2. The model

As discussed above, in this paper, we decompose community's decisions on erosion control and/or reforestation into two steps: first, the community agrees on whether or not to undertake an activity and then, they determine how much to reforest and/or how much soil erosion to actually do.

2.1. A binary decision

The first step is a binary decision, undertake or not reforestation or stone bunds construction. Empirically, 50% of interviewed communities were engaged in the construction of stone bunds in 2002, and 41% in reforestation (32% engaged in both activities, while 41% in neither). We hypothesize that these decisions are mainly dependent on the cooperative capacity of a community, and on the presence of a project promoting those activities through financial and technical support. Several other factors will also affect this decision, including human capital, land scarcity, a measure of whether benefits accrue to community members or to non-members as well, a measure of the opportunity cost of household labor, and measures of expected benefits and costs; we discuss each of these in turn below. But first, we specify the investment relationship in equation [1] below:

Ero / Ref = f(AC ; PSB-GTZ ; Educ ; LM; Crop ; Strang ; Mig ; Water) [1]

Ero	= Probability of a village to be involved in stone bunds construction.
Ref	= Probability of a village to be involved in reforestation.
AC	= Cooperative capacity of the community
PSB-GTZ	= Period the village works with the PSB/GTZ.
Educ	= % of adults with education (public or alphabetization in local language)
LM	= Existence of land market in the village
Crop	= % cropped land
Strang	= % of the population cropping seasonally on the village land.
Mig	= % household with long term migration.
Water	= Water points in the village (only for reforestation)

Indicators of cooperative capacity constructed in the next section are expected to have a positive impact on the decision to undertake both activities. An NGO (locally based but supported with international donor funds), the Programme Sahelian Burkinabe supported by the German Agency for Technical Cooperation and Development (PSB/GTZ), is the main project acting in the surveyed zone, and has been operating since the beginning of the 80's (75% of surveyed villages have been working with PSB/GTZ). There have been three distinct conceptual frameworks guiding project implementation until now. Before 1996, the project had an overwhelming focus on technical solutions to crop production and an NRM focus on specific resources within given boundaries (the latter referred to as the "terroir" approach). Projects starting after 1996 expanded on the "terroir" approach to consider the system as a whole, including community members' use of non-community resources and vice-versa. In 2000, emphasis within PSB/GTZ program sharpened the focus on conflict management. Whereas the presence of PSB/GTZ is expected to increase a community's decision to engage in reforestation and/or soil erosion control, dummies capturing the different time period when the project began working in a community are constructed to allow for different "project paradigms" to have a differential impact on community participation in these activities – with "no PSB/GTZ" being the omitted category.

The proportion of households having at least one adult with some education – public education or alphabetization in local language - is expected to increase the likelihood that these activities are undertaken, both because greater education should lead to enhanced capacity to understand the need for collective action given the interdependencies involved in public goods provision, and because the "school" is often used as a meeting place by alumni and current parents to plan collective activities.

The presence of a land market in the village reveals a certain degree of land scarcity. The creation of a land market presumes greater tenure security, and to the extent this is true, landowners should be more willing to invest in productivity improving technologies (Meizen-Dick, 2002), particularly on private croplands. Similarly, we hypothesize that villages whose land is mostly allocated to cropping activities are more likely to undertake the stone bunds/reforestation investments than those with a greater specialization in livestock production, since we expect that returns to soil erosion control will be relatively greater for crops than for livestock.

The presence of 'outsiders' in the village implies that such outsiders might benefit from soil erosion control measures but are unlikely to bear any costs associated with providing these measures; to capture this potential impact, we use the proportion of crop farmers that are not settled in the village but who crop on borrowed land. Higher opportunity costs of labor dedicated to constructing bunds or reforesting is expected to reduce the likelihood of undertaking such measures; given rather thin local labor markets, however, establishing this opportunity cost is difficult to do directly. Instead, we use the proportion of households with at least one member engaged in long-term migration. Finally, in the case of reforestation, we expect that villages with greater water infrastructure (number of water points such as forages, well, pounds) are more likely to engage in reforestation, since water is the main constraint for trees to survive and thus costs of reforesting should be lower. The largest non-labor costs associated with constructing stone bunds are related to transporting stones; we expect that villages where PSB/GTZ is operating face lower costs of finding sources for stones and in transporting them back to the village, as PSB project personnel actively support this activity. In other words, we do not have a separate proxy for costs of constructing stone bunds; rather, we expect villages with a PSB/GTZ presence to be more likely to engage in stone bunds or reforestation both because of its emphasis on NRM more generally, and because in such villages, costs of constructing stone bunds should be lower.

2.2. Efficiency in the provision of NRM technologies

Once the village members agree to engage in an activity, the next decision is how much reforestation or stone bund construction to undertake; this results in the expected outcome (planned reforestation, bund construction) and input demand (monetary or labor contributions by members[1]). At the same time, we would like know whether or not the group is efficient at providing reforested areas or stone bunds. We thus derive a measure of the degree of inefficiency, and then use exogenous community characteristics to explain this degree of inefficiency, including the capacity of the community to cooperate. First, we build a stochastic frontier model to estimate the technical efficiency[2] of communities in the construction of stone bunds and in reforestation.

Suppose, the community has a production function $f(w_i;\beta)$ and, if all were efficient, the community would produce $Inv = f(w_i;\beta)$, where w_i, is labor provided by community members, β is the shifter in production, and Inv_i is the level of NRM investment provided. In the case of reforestation, *Inv* represents the number of trees planted, and in the case of stone bunds, the number of hectares treated by stone bunds. Additionally, constructing stone bunds is often undertaken in conjunction with other investments whose purpose is to increase productivity, such as improved traditional planting pits (*zai*), manure application, or mulching (*paillage*). These technologies are complementary and, in practice, it is simply not possible to decompose labor allocation between each technology, stone bunds included. Therefore, we built a composite variable called *Improved bunds*, which is equal to the area treated by stone bunds, weighted by an index aggregating the percentage of this land treated with complementary technologies[3].

[1] We observe only few cases of monetary contribution (2 cases for the reforestation and 4 cases for stone bunds construction), therefore monetary participation has not be taken into account in the following analysis.
[2] Since as we will see later, the production function is defined with a single input , we are not interested in measuring allocative efficiency.
[3] This index has been built using a factor analysis.

Allowing for the possibility of inefficiency, we can re-write the producers' production function as follows: $Inv_i = f(w_i;\beta)\xi_i$, where ξ_i is the level of efficiency for community i (ξ_i=1 if the community achieves the optimal output , ξ_i<1 otherwise). On the other hand, output is also subject to random shocks, v_i, that are not controllable by the community: $Inv_i = f(w_i;\beta)\xi_i e^{v_i}$. Taking the natural log of both side yields:

$$\text{Ln}(Inv_i) = \beta_0 + \beta \ln(w_i) + v_i - u_i \qquad [2]$$

where $u_i = -\ln(\xi_i)$ is the degree of technical inefficiency.

2.3. Explaining efficiency level in the provision of NRM technologies

From the above analysis, we can derive a measure of inefficiency for each community, $u_i = -\ln(\xi_i)$. We are then interested in determining what factors affect the degree of efficiency; as captured in eq. [3] below:

ξ_i= g(AC/Particip; PSB-GTZ; Educ; LM ; Strang ; Mig; Expe; Water/Distance) [3]

AC	= Cooperative capacity of the community
Particip	= Participation rate of community members
PSB-GTZ	= Activity supported by PSB/GTZ, vs. other projects.
Educ	= % of adults with education (public or alphabetization in local language)
LM	= Existence of land market in the village.
Strang	= % of the population cropping seasonally on the village land.
Mig	= % household with long term migration.
Expe	= Past experience in activity
Water	= Water points in the village (only for reforestation)

First, we are interested in observing the impact of cooperative capacity and the participation rate on the degree of inefficiency in communities that reforest or construct stone bunds. However, both variables cannot enter the same regression equation, since they are endogenously related; i.e., higher cooperative capacity induces greater participation in a specific activity. We thus show results for two specifications, each using one or the other variable. We hypothesize that in communities with a greater capacity to cooperate, or a higher participation rate in the activity under study, will be more efficient in producing the public good.

The project supporting the activity may also influence inefficiency; thus we include the PSB-GTZ variables described above. Furthermore, we expect that previous experience in providing the good, i.e. previous area treated for soil erosion, and number of years community members have engaged in reforestation activities, is expected to have a positive impact on efficiency (or alternatively, a negative impact on inefficiency).

Greater water infrastructure, used to proxying costs of accessing water, is not only expected to increase the area planted, but also to increase efficiency since timing of water applications is thought to be critically important, particularly for very young trees. Finally, we expect education, land market, the presence of outsiders, extent of long-distance migration, to have similar effects on efficiency that they have on the decision to undertake the activity.

Because we only observe the efficiency level of communities that undertake the activity only, and we expect that the communities that did not engage in the activity are likely to also be those that are less efficient, we suppose a selection bias that will cause the overestimation of the efficiency level. In order to correct for this potential bias, we calculate the inverse Mills ratio, computed from the selection equation, and use this as a regressor in the inefficiency equations.

3. Data collection

Data were collected in 78 communities in the Seno and Oudalan regions of Burkina Faso in the summer 2002. An institutional questionnaire was administered collectively to the village leader, representatives of the major NRM institutions and other key informants. Three broad types of data were collected. First, a census was taken of all institutions (e.g. the chief) and organizations in charge of any aspect of NRM, and detailed information was recorded regarding the structure of management, how the organization was created and who/what group began the organization, the number of members, frequency of meetings and attendance at those meetings, etc. This section was followed by an enumeration of all activities related to NRM in the community with detailed information on the activities, the institution or organizations responsible, methods of monitoring and enforcing participation, and actual participation rates. This part of the survey was structured to gather information by resource: common pastures, water sources, soil, and tree resources. The final section of the survey gathered information on rules and regulations, following a similar format to that for the activities section.

Data on the main characteristics of the community were also collected in a community-level questionnaire, such as basic demographic data (number of households by ethnicity, number of female-headed households, number of quarters (define quarters) within the village, etc.), herd demography and mobility, community infrastructure, and identification of major markets used by community members. In addition, aerial photographs were used to construct resource maps for each community, and to identify community boundaries – including identification of areas over which resources were shared with other communities. Boundary coordinates were also obtained with GPS units. Resource maps included information on land use and soil types, key resources such as water points and sand dunes, and the location of the village, hamlets and roads.

4. Measuring the cooperative capacity

The level of cooperative capacity in a community is not directly observable, and we must therefore construct a proxy measure of such capacity. Thus, our purpose in this section is to aggregate several indicators of collective action using a factor analysis (McCarthy et al, 2002) in order to arrive at proxy measures of cooperative capacity. These indicators can be regrouped into two sets of variables. The density of organizations and the participation rates by households in these organizations reflect the capacity to share information and facilitate the transformation of information into knowledge and action. The second set of variables includes the frequency of and attendance at meetings, the number of rules and regulations devised and activities undertaken, and whether or not labor contributions are made. These characteristics are thought to reflect the capacity of the community to translate "social capital" into concrete action, which bears a relationship with the concept of "agency" as discussed in Krishna (2002).

More specifically, the variables used in the factor analysis to recover cooperative capacity are as follows:

- NRM Network: Number of NRM institutions/organizations per household

- NRM Membership: Percent of households that are members of NRM institution/organizations, averaged over all NRM institutions, multiplied by the number of these organizations
- Non-NRM Network: Number of non-NRM institutions/organizations per household (i.e.. women's groups)
- Meetings: Number of meetings held per year, averaged over all NRM organizations
- Average Meetings Participation Rate: We asked how many households "usually" attended meetings; this number was used to create the percent of households attending meetings for each institution, and a variable was constructed of the average of this percent across organizations.
- Activities: Total number of activities observed for all NRM organizations
- Rules: Total number of rules observed for all NRM organizations
- Average number of workdays allocated to collective activities, per member
- Average Activities Participation Rate: As with the meetings variable, the percent of households "usually" participating was constructed, and an average was taken across organizations.

Because these variables are strongly correlated, but no one variable is thought to adequately capture the cooperative capacity of a community, we have aggregated the variables into indices based on a factor analysis. Results of the factor analysis for the first two factors, which had eigenvalues greater than one, are presented below.

	First Factor	Second Factor
Eigenvalue:	2.12	1.73
Cumulative:	.52	.95

To highlight scoring coefficients with strong loadings, we have put those with coefficients greater than |.1| in bold. Looking at the first factor in table 1, we note that the scoring coefficients are relatively high and positive for the network and membership variables and to a lesser extent on percent of members who actually contribute labor and number of activities, but coefficients are relatively low for participation in meetings, and activities, total number of rules and of days worked. Given these scoring coefficients, we hereafter refer to this factor as the indicator of network capacity (INC).

Table 1. Scoring coefficients for the first two factors

Variables	INC	IIC
Network NRM	**0.32**	**-0.19**
Network others	0.08	-0.01
Membership NRM	**0.51**	**-0.23**
# meetings	-0.04	0.08
Participation meeting	0.02	0.08
# Activities	**0.16**	**0.28**
# Rules	0.01	0.03
# Days of work	0.05	**0.15**
Participation in work	**0.18**	**0.46**

In contrast, scoring coefficients for the second factor are strong and positive for most of the variables measuring active participation –number of activities, participation in activities and the number of days worked. The coefficients for density and membership in organizations are actually negative on this index. Given the heavier weight on variables associated with making and implementing decisions, we hereafter refer to this factor as the indicator of implementation capacity (IIC).

5. Empirical results

5.1 Probability to engage in NRM investment

The first stage of the analysis consisted in defining the determinants of communities' decision to undertake NRM investment. Using Probit analysis, we estimate equation [1] with stone bunds construction and reforestation as our dependent variables. Results are reported in the first column of tables 2 and 3. First, we note that cooperative capacity does increase the probability that communities undertake public goods provision; implementation capacity being statistically significant in both equations, and network capacity being statistically significant in the reforestation equation. We hypothesized that in villages where PSB/GTZ has a presence, there would be a greater probability of community-level decisions to provide public goods; in estimated equations we include dummies that capture the different length of time PSB/GTZ has been active in the communities to allow for different effects due to accumulated experience and different paradigms influencing project implementation. Experience with PSB/GTZ increases the probability that a community will undertake stone bund construction for all three time periods capturing the length of tie PSB/GTZ has operated within the community as compared to control villages; for reforestation, only those villages where PSB/GTZ has operated between 1996 and 1999 have a higher probability of engaging in reforestation activities.

Communities whose land is mostly allocated to cropping activities are more likely to get involved in NRM investments as expected. The land market dummy, which captures resource scarcity, has no statistically significant effect, nor does the region or the water points for reforestation. Among demographic variables, education and long term migration favors SB, but has no effect on reforestation. On the other hand, presence of "outsiders" accessing community decreases the probability of SB construction and reforestation.

5.2. Explaining communities efficiency in public good provision

Based on equation [2], we run a cross-sectional stochastic frontier model to obtain measures of inefficiency in reforestation and stone bunds construction. Average efficiency level are reported in table 4 in annex, with other descriptive statistics. Communities are more efficient in stone bunds construction (technical efficiency of 67%) than in reforestation (45%).

Once efficiency is measured, we are explaining differences observed between communities. We estimate equation [3] with OLS using two scenario: 1) we introduce cooperative capacity index as explanatory variables, 2) we use the participation rate instead of the cooperation variables. Results are reported in the last two columns of tables 2 and 3.

Regarding the effect of cooperation on efficiency, results show that network capacity has a negative impact on the reforestation efficiency - greater networks, i.e. more organizations and membership in the community and less efficient is the reforestation work - and the participation rate has a negative impact on SB construction.

The first result can be interpreted as a coordination problem when too many organizations are in charge of NRM in the community and when NRM activities are organized by more than one organization. The current institutional changes that are taking place in the region with the creation of CVGT (village committee for territory management), which mandate is to coordinate NRM at the village and inter-village level (GRAF, 2003, p.22), could reduce this weakness and result in greater efficiency in the provision of investments. The second result is quite surprising, one interpretation could be that the closest the participation rate is from 100% and the greater probability the group includes less motivated participant that might reduce the average labor productivity.

Table 2: Engagement in stone bunds construction and efficiency in provision

	Selection		Efficiency (1)		Efficiency (2)	
Cooperation						
INC	1.713	1.5 *	-0.016	-0.1		
IIC	1.060	2.3 ***	-0.155	-0.6		
Labor participation rate					-0.187	-1.8 **
PSB/GTZ						
Villages before 1996	0.440	2.0 ***				
Villages 1996-99	0.648	3.1 ***				
Villages 2000	0.413	2.1 ***				
Land characteristics						
% Cropland	0.566	1.6 *				
Oudalan region	0.173	0.9				
Land market	0.115	0.6	0.119	2.3 ***	0.152	2.9 ***
Demography						
% Education	0.951	3.5 ***	0.087	1.1	0.087	1.2
% Outsiders	-1.276	-2.7 ***	-0.415	-1.2	-0.291	-0.9
% Long term migration	0.682	1.5 *	-0.125	-0.4	0.026	0.2
Activity specific						
Experience			0.002	2.5 ***	0.003	2.9 ***
Mills ratio			-0.103	-1.3	-0.130	-1.7 **
Constant			0.714	2.7 ***	0.708	7.0 ***
R2	0.510		0.46		0.51	

Probit estimation for the selection equation, OLS estimation for the selection equations

Number of observations: 78 (selection), 39 (efficiency)

* (**) (***) Indicates coefficient significant at more than 85% (90%) (95%).

The presence of land market in the community boosts efficiency in SB construction, which is done on private land, whereas it has negative but not significant impact on reforestation which has a greater public component. Surprisingly, water availability plays against efficient reforestation. Demography variables are not playing in both equations, except for long term migration that induces more reforestation efficiency. Past experience in the provision of the good is valuable in the case of erosion control only.

Table 2: Engagement in reforestation and efficiency in provision

	Selection		Efficiency (1)		Efficiency (2)	
Cooperation						
INC	0.806	1.9 **	-1.679	-2.4 ***		
IIC	1.247	3.4 ***	0.588	0.8		
Labor participation rate					-0.188	-0.7
PSB/GTZ						
Villages before 1996	0.251	1.3				
Villages 1996-99	0.256	1.5 *				
Villages 2000	-0.025	-0.1				
Land characteristics						
% Cropland	0.464	1.5 *				
Oudalan region	0.060	0.5				
Land market	-0.145	-1.1	-0.187	-1.3	-0.118	-0.8
Water points	0.029	1.0	-0.071	-2.6 ***	-0.048	-1.7 **
Demography						
% Education	0.253	1.2	0.279	1.4	0.126	0.6
% Outsiders	-1.659	-1.9 **	0.321	0.2	1.056	0.7
% Long term migration	-0.048	-0.1	1.721	2.2 ***	0.053	0.1
Activity specific						
Experience			-0.002	-0.3	0.007	0.1
Mills ratio			-0.239	-1.2	-1.179	-0.9
Constant			0.601	0.9	0.858	2.4 ***
R2	0.37		0.450		0.300	

Probit estimation for the selection equation, OLS estimation for the selection equations
Number of observations: 78 (selection), 30 (efficiency)
* (**) (***) Indicates coefficient significant at more than 85% (90%) (95%).

Finally, selection bias is occurring in scenario 2 of the SB equation, with a negative coefficient for the Mills ratio, suggesting as expected that villages that engaged erosion control activity are more likely to be efficient.

6. Conclusion

This paper is an analysis about the importance of collective action for the realization of Natural Resource Management (NRM) investments and also on its potential side effect on efficiency. The analysis is based on survey data that were collected in 2002 in 78 villages of northeastern Burkina Faso. Community involvement decision in soil erosion control and in reforestation is first analysed and efficiency in the realization of these investment is measured and explained using exogenous factors. The general cooperative capacity of each community is first recovered for any type of collective activity and then, is successfully used to explain the probability for a community to get involved in specific NRM investments. However, network capacity has a negative impact on reforestation efficiency, suggesting than a better coordination between the multiple NRM organization of the village is necessary. The recent creation of the CVGT should solve this matter.

In parallel, we show that more participants in collective work leads to a lower efficient rate. A better understanding of the rules of the work organization and the expectations in members behaviors could help clarify this issue, and therefore help to define institutional arrangements that can be put in place in order to avoid this ‘waste’ of volunteer work.

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ANNEX

Table 4. Variables description

Variables	Nb obs	Mean	Std. Dev.	Min	Max
Efficiency					
Stone bunds	39	0.669	0.158	0.348	0.919
Reforestation	31	0.446	0.285	0.077	0.973
Cooperative capacity					
INC	78	0.179	0.148	0	1
IIC	78	0.654	0.203	0	1
PSB-GTZ					
Before 1996	78	0.256	0.439	0	1
1996-99	78	0.218	0.416	0	1
Demography					
% Education	78	0.293	0.324	0	1
% Outsiders	78	0.093	0.218	0	1
% Long term migration	78	0.097	0.126	0	0.846
Community land					
Land market	78	0.295	0.459	0	1
% Cropland	78	0.417	0.206	0.063	0.902
Water points	78	4.01	2.07	1	10
Stone bunds specific					
Past treated area	39	21.19	24.91	0	135
Support by PSB-GTZ	39	0.897	0.307	0	1
Participation rate	39	0.770	0.242	0.095	1
Distance to stones	39	9.64	11.05	1	50
Reforestation specific					
Experience (Nb years)	30	11.20	7.37	1	30
Support by PSB-GTZ	31	0.839	0.374	0	1
Participation rate	31	0.752	0.213	0.143	1