**Impact of water and soil conservation techniques adoption on cereal crop productivity in Burkina Faso**

**Abstract**

In Burkina Faso, the agricultural sector is at the heart of economic policies. The sector is dominated by cereal production, which takes up more than half of arable land. However, declining soil fertility is a major problem for increasing agricultural productivity. Faced with this problem, water and soil conservation techniques need to be adopted. This research analyses the impact of water and soil conservation techniques adoption on cereal productivity in Burkina Faso. Multinomial endogenous treatment effect model is used with data from 1741 households. The results show that the adoption of water and soil conservation techniques contributes to increased cereal productivity in Burkina Faso, as households adopting organic manure, zaï and stone cordons have higher cereal productivity than those not adopting the techniques. In addition, the combined adoption of zaï and organic manure, and the combination of stone cordons and organic manure, offer higher cereal productivity gains than individual adoption. Sustainable improvements in cereal productivity require the strengthening of improved land management practices such as water and soil conservation techniques. Policies aimed at enhancing the value of organic manure would improve the effectiveness of zaï and stone cordons and increase cereal productivity in Burkina Faso.

**Keywords**: water and soil conservation techniques, cereal productivity, multinomial endogenous treatment effect model, Burkina Faso

**JEL Classification** : D04 P26 Q55

# **Introduction**

Agriculture is a key component of Burkina Faso's economy. Agricultural sector contributes 35% of the gross domestic product (GDP) and employs approximately 82% of the working population (FAO 2019). Agriculture is essentially rainfed and dominated by cereal production (sorghum, maize, millet), which accounts for more than 70% of the total cultivated area (FAO 2019). However, agriculture remains rain-fed and has few means to anticipate and mitigate the effects of climate variability. According to Teklewold et al. (2013), rainfall variability creates favourable conditions for the growth of pathogens and causes a reduction in soil water content, leading to inappropriate crop growth. Heavy rainfall leads to significant crop yield losses, seriously affecting land productivity and rural household incomes. Similarly, soil degradation combined with inappropriate agricultural practices an unfavour factor for improving agricultural productivity and reducing food insecurity in Burkina Faso (Salaisook et al. 2021). The weakness of Burkina Faso's agriculture has led to malnutrition affecting nearly 20% of the population, with stunting among children under 5 years of age (FAO 2019).

In such a context, integrated soil fertility management is needed to increase agricultural productivity and combat food insecurity. This involves the adoption of resilience strategies such as the use of early varieties, crop rotation and diversification, and soil conservation techniques. Soil fertility management helps to protect against climate risks, reduce nutrient depletion and improve food security (Katengeza et al. 2019). According to Zougmoré et al. (2016), the adoption of water and soil conservation techniques can help increase agricultural productivity while mitigating the adverse effects of climate change and preserving the health of the environment. Amfo et al. (2021) noted that water and soil conservation techniques enable the soil to maintain its productive capacity, combat erosion and provide the minimum conditions for plant biological activity, i.e. photosynthesis and nutrient uptake by roots. Zougmoré et al. (2016) recommended improving the effectiveness of these techniques by applying organic fertiliser. However, Di Falco et al. (2011) and Lesur-Dumoulin et al. (2017) reported that cropping techniques based solely on water and soil conservation techniques lead to low productivity.

Furthermore, the majority of empirical studies fail to consider the potential complementary and substitution relationships that may exist between soil conservation techniques (Abdulai and Huffman 2014; Amfo et al. 2021). This research contributes by examibing not only individual effects, but also the combined effects of adopting different technologies. Indeed, the choice of a production technology may depend on the technologies already used by the farmer, and not considering this potential interdependence or simultaneous adoption through an isolated analysis may lead to an under- or overvaluation of the technology (Wu and Babcock 1998). Therefore, the general question of this article is follows: What is the impact of water and soil conservation techniques on cereal productivity in Burkina Faso?

The general objective of this paper is to analyse the impact of water and soil conservation techniques on cereal productivity in Burkina Faso. More specifically, it aims to

1. Identify the factors that explain the adoption of soil and water conservation techniques;
2. Determine the impact of the adoption of water and soil conservation techniques on cereal productivity in Burkina Faso.

To achieve our objective, we assume the following:

1. Factors such as off-farm income, agricultural vocational training and climatic zone influence the adoption of water and soil conservation techniques,
2. The adoption of water and soil conservation techniques improved cereal productivity in Burkina Faso.

The remainder of the paper is divided into four sections. Section 2 reviews previous work. Section 3 presents the methodological approach and the data. Section 4 discusses the results. Section 5 concludes with policy implications.

# **Literature review**

## **Description of water and soil conservation techniques in Burkina Faso**

Developed in the 1970s and 1980s to address the humanitarian and environmental crises in Sahel countries, several agricultural innovations have been implemented by researchers and farmers to combat erosion and the decline in the fertility of cultivated land. In Burkina Faso, the main innovations are the application of organic manure, zaï and stone cordons. These efforts aim to improve soil management and increase the productivity of farmland.

Organic manure: It is a natural fertiliser made from animal waste and crop residues. It enriches the soil by improving its chemical and physical composition. It also provides nitrogen in a usable form, reduces greenhouse gas emissions and helps plants grow better without burning roots or destroying beneficial microorganisms in the soil.

Zaï: This is a traditional soil restoration technique that involves digging holes by hand to collect surface runoff and retain organic matter. It improves soil permeability and increases cereal and straw production, thereby increasing the income of smallholder farmers. However, the effectiveness of this practice depends on the availability of organic resources.

Stone cordons: These are anti-erosion devices consisting of blocks of stones arranged in one or more rows along contour lines or around a field. They help restore degraded land, combat water erosion, improve water infiltration and facilitate the vegetative development of crops when combined with the addition of organic matter, the use of zaï or crescents (Zougmoré, 2016).

## **Related literature review**

According to Long et al. (2016), the concept of eco-innovation or environmental innovation offers some value to the analysis of technological innovations such as water and soil conservation techniques. Indeed, the concept of eco-innovation represents the process of developing new products, processes or services that add economic value, while substantially reducing environmental impacts (Horbach et al., 2012). These technologies improve the productivity of agricultural land by simultaneously reducing the risks associated with climate change and greenhouse gas emissions. Water and soil conservation techniques positively affect agricultural productivity as they reduce erosion, increase soil moisture and lead to increase land productivity (Haregeweyn and al., 2015). They also make it possible to identify locally appropriate solutions to agricultural management for sustainable development and food security in the context of climate change (Collins and Peron, 2018). Following Zougmoré and al. (2018) and Ouiminga (2022), water and soil conservation techniques can sustainably improve agricultural productivity, rural livelihoods and the adaptive capacities of farmers and production systems, while contributing to climate change mitigation. In addition, the adoption of water and soil conservation practices reduces the negative impacts of climate change and increases agricultural productivity by curbing the spread of land degradation problems, improving soil structural stability and increasing its organic matter content (Amfo and al., 2021). However, some authors indicate that water and soil conservation techniques lead to low levels of agricultural productivity.

Lesur-Dumoulin and al. (2017) reported that cropping systems based solely on technologies such as zaï, living hedges, half-moons, bunds, stone cordons and organic fertilisation lead to low yields. Similarly, Di Falco and al. (2011) revealed that the adoption of soil and water conservation techniques is not associated with an increase in agricultural productivity. In the same vein, Pan and al. (2021) find that agroecological innovation makes it possible to reconcile the issues of productivity and environmental protection, but creates additional uncertainties for farmers who are already faced with numerous risks such as price volatility and regulatory constraints.

There is therefore some controversy about the empirical relationship between soil and water conservation techniques and agricultural productivity. However, some studies consider the different technologies as equivalent. For example, Abdulai and Huffman (2014) considered the adoption of water and soil conservation techniques as a binary variable, whereas the effects of each technique are different. This research contributes to the literature in two ways. First, the individual effects of different water and soil conservation techniques, such as zaï, organic manure and stone cordons are analyse. Second, it considers the combined adoption of zaï and organic fertiliser and the combination of stone cordons and organic fertiliser. According to Wu and Babcock (1998), failure to consider of the simultaneous adoption of several technologies may lead to an under- or overestimation of the influence of the different techniques, since the choice of a water and soil conservation technique may depend on the techniques already used by the farmer.

# **Methodology and data**

## **Methods for analysing the impact of water and soil conservation techniques on cereal productivity in Burkina Faso**

Econometric approaches such as propensity score matching and instrumental variables are commonly used to address selection bias in cross-sectional data. However, the problem with propensity score matching is that it does not control for the unobserved heterogeneity used in this study. It is possible that unobserved characteristics affect the probability of adopting water and soil conservation practices. Failure to account for these unobservable variables may challenge the assumption of conditional independence and bias the estimates of the average treatment effect (ATT). To correct for these biases, a multinomial endogenous treatment effect model developed by Deb and Trivedi (2006) is used as it corrects for unobservable bias and produces consistent estimates.

The multinomial endogenous treatment effect model proposed by Deb and Trivedi (2006) has two components: the treatment equation and the outcome equation. These equations are linked by observed and unobserved characteristics.

Given that  binary variables represent the choices observed by the household, the probability of a household choosing alternative j can be modelled via a mixed multinomial logit model. The model is represented by the following equation (Deb and Trivedi, 2006):

 (1)

Where  (1=organic manure, 2=zai, 3=joint use of zai and organic manure, 4=stone cordons, 5=joint use of stone cordons and organic manure, 0=no technique used).  represents the socioeconomic characteristics of the household,  is a latent factor incorporating unobserved factors common to the treatment choice and outcome of household i,  and  are factor loading parameters representing observed and unobserved individual heterogeneity affecting household utility.

The expected value of the output equation (cereal productivity) for household i can be formulated as follows:

 (2)

Where  is a set of exogenous covariates, , ,  and  , ,  are parameters associated with exogenous covariates and dummy variables that explain cereal productivity. are latent factors representing the effects of unobserved characteristics on cereal productivity and selection in the treatment. The factor loading parameter  represents the correlation between the intensity of water and soil conservation techniques adoption and grain productivity on the basis of unobservable characteristics. The joint estimation of equations (1) and (2) is carried out via the simulated maximum likelihood method on the basis of Halton sequences.

## **3-2 Description of variables**

Adoption of water and soil conservation techniques: The adoption of water and soil conservation techniques is measured in two ways. The first is a set of binary variables taking the value 1 if the household adopts zaï, stone cordons and organic manure. The second is a categorical variable that takes the value 0 if the household does not use any technique, 1 if it uses organic manure, 2 if it uses zaï, 3 if it combines zaï and organic manure, 4 if it uses cordons pierreux and 5 if it combines cordons pierreux and organic manure. According to Zougmoré et al. (2016), the adoption of water and soil conservation techniques helps to increase agricultural productivity while mitigating the negative impacts of climate change and preserving the health of the environment. Furthermore, households are likely to adopt a combination of techniques to address a variety of production constraints in order to increase their productivity (Asfaw et al, 2016). The combination of zaï and organic manure, and that of stone cordons and organic manure, are expected to provide higher cereal productivity gains than individual adoption.

Other factors such as the age of the head of the household, level of education, gender, household size, off-farm income and agro-climatic characteristics of the farms, such as soil types, may also be determinants of cereal productivity. Table 1 describes the variables used to analyse the effect of adopting soil and water conservation practices on cereal productivity.

**Table1**. Summary of variables and expected signs

|  |  |  |
| --- | --- | --- |
| **Variables** | **Description** | **Expected effect** |
| **Result variable** | |  |
| Cereal productivity | Total production of the main cereals per hectare measured in kilograms per hectare (kg/ha). |  |
| **Explanatory variables** | | |
| Adoption of water and soil conservation techniques | Categorical variable taking 1 if the household uses only organic manure,2 if the household uses only zaï,3 if the household uses zaï and organic manure,4 if the household uses only Stone cordons,5 if the household uses Stone cordons and fertiliser,6 if the household uses zaï, Stone cordons and organic manure. | + |
| Age | Age of head of household in years | +/- |
| Gender | 1 if the head of household is a man and 0 if he is a woman | + |
| Rainfall | Precipitation in millimetres | + |
| Cereals area | Cereal area in hectares |  |
| Education | 1 if the head of household has completed primary education, 2 if he or she has completed secondary education and 0 if he or she has received no formal education | + |
| Agricultural vocational training | 1 if the head of household has received agricultural vocational training and 0 otherwise | + |
| Type of soil | Categorical variable with values of 1, 2, 3, 4 and 5 respectively for clay, sand, gravel, dryland and laterite soils. | +/- |
| household assets | Number of persons in the household who are working |  |
| Non farm income | Income from non agricultural activities measured in FCFA | + |

Source: Authors based on PNGT2 data (2016-2017)

## **3-3 Data**

### **3-3-1 Data sources**

The data used in this essay are from the Survey of Living Conditions in Rural Households, which was conducted as part of the Second National Land Management Programme. These data are microeconomic data collected between July and August 2017. The data collection covered the 45 provinces of Burkina Faso and included several agricultural products. Regional stratification was used to obtain representative observations of the population. Sampling was carried out at the village level in the country and at the household level in the village.

Villages were selected on the basis of a quota of 6 villages per province. To do this, the team obtained a list of the names of all the localities in Burkina Faso, including the main towns of the communes. After the communes were eliminated, the villages whose numbers appeared in the first six positions of the random ranking were selected.

Once the villages had been selected, the survey team carried out an exhaustive census of the concessions and households in each village, systematically assigning a number to each. The size of the population thus defined constituted the sampling frame. Once all the households living within the village boundaries had been counted, the households in the village were grouped into three categories according to the type of traction used; before being drawn at random.

After data processing, the information collected on household socioeconomic and demographic characteristics, cultivation practices and cereal production in the 2016/2017 agricultural season was retained for analysis. A sample of 1741 households was selected for analysis.

### **3-3-2 Household characteristics analysis**

Proportion of different techniques used

Table 2 shows a low rate of adoption of water and soil conservation techniques in Burkina Faso. In fact, 34.84%, 3.09% and 2.35% of households have adopted organic manure, stone cordons and zaï respectively. 2.81% of households have adopted both organic manure and stone cordons, and 3.61% of households combine zaï and organic manure.

**Table 2** Percentage of households adopting technologies

|  |  |
| --- | --- |
| **Soil conservation techniques** | **Percentage (%)** |
| 0 technique | 53.30 |
| Organic manure | 34.84 |
| Zaï | 2.35 |
| stone cordons | 3.09 |
| Organic manure + stone cordons | 2.81 |
| Organic manure +zaï | 3.61 |

**Source**: Author based on PNGT2 data (2016/2017)

**Testing the difference in cereal productivity between adopters and nonadopters of different water and soil conservation techniques**

Tables 3 and 4 show that the average age of the surveyed heads of households varies between 48 and 50 years for adopters of water and soil conservation techniques, and 47 years for non-adopters.

The rate of agricultural vocational training is very low in Burkina Faso, with only 4% to 5% of adopters having received agricultural vocational training. It is also clear that men have a monopoly on decision-making in Burkina Faso. Men are the heads of household for 89.92% of the zaï adopters, 95.35% of the organic manure adopters and 90.65% of stone cordon adopters. Among the adopters of various water and soil conservation techniques, only 10-15% have primary education and 5-10% have secondary education.

Households with active members have a high propensity to use zaï and stone cordon, as the number of active members in households using zaï and stone cordon is estimated at 4, compared with 3 for organic manure. In terms of income, zaï and organic manure adopters have a higher average income than nonadopters do, whereas stone cordon adopters have a lower average income than nonadopters do. Adopters have average incomes of 330 199 FCFA for zaï, 374 222 FCFA for organic manure and 308 343 FCFA for stone cordons, whereas the average incomes of nonadopters are estimated at 316 974 FCFA, 277 182 FCFA and 318 733 FCFA for zaï, organic manure and stone cordons, respectively.

The average cultivated area is 2.736 ha for zaï adopters, whereas it is 2.898 ha for organic manure adopters and 2.502 ha for stone cordon adopters. Most households that have adopted different water and soil conservation techniques live in the Sahel zone. The proportion of adopters is estimated at 48.062% compared with 7.882% for zaï, 14.361% compared with 8.180% for organic manure and 30.215% compared with 9.14% for stone cordons.

The difference test on observable characteristics allows us to examine the similarity between households that use water and soil conservation techniques and those that do not. The results in Table 4 show significant differences in cereal area, household assets, income, climate zone, soil type and agricultural education. The test also revealed that households that use organic manure have higher cereal productivity than those that do not use organic manure, whereas those that use zaï have lower productivity. However, these results do not reflect the real impact of adopting water and soil conservation techniques on cereal productivity, as adopters and nonadopters are not similar in terms of all observable characteristics. It is therefore necessary to use a model that neutralises the selection bias due to differences in observable and unobservable characteristics between the two groups.

**Table 3.** Difference test for observable characteristics before matching

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
|  | **Zaï** | | | **Organic manure** | | |
| **Variables** | **Adopted** | **Non adopting** | **Différence** | **Adopted** | **Non adopting** | **Difference** |
| Gender (1=man) | 89.922 | 93.561 | -3.639 | 95.345 | 91.819 | 3.526\*\*\* |
| Agricultural vocational training (1=yes) | 5.42 | 3.67 | 1.75 | 5.718 | 2.406 | 3.312\*\*\* |
| Education | | | |  |  |  |
| None | 77.519 | 81.061 | -3.542 | 79.627 | 81.66 | -2.033 |
| Primary | 15.503 | 13.811 | 1.692 | 15.312 | 12.934 | 2.378 |
| Secondary | 6.976 | 5.126 | 1.85 | 5.059 | 5.405 | -0.346 |
| Age (year) | 47.627 | 47.399 | 0.228 | 48 | 47 | 1 |
| (1.189) | (0.345) | (0.498) | (0.443) |
| Area under cereals (ha) | 2.7360 | 2.7364 | -0.0004 | 2.898 | 2.618 | 0.28\*\* |
| (0.201) | (0.062) | (0.104) | (0.069) |
| household assets (number of people) | 3.912 | 3.834 | -0.077 | 4.135 | 3.628 | -0.507 \*\*\* |
| (0.220) | (0.053) | (0.089) | (0.061) |
| Non farm income (FCFA) | 330199 | 316974 | 13225 | 374222 | 277182 | 97040 |
| (33589.68) | (9470.019) | (15290.33) | (10982.42) |
| Climate zone | | | |  |  |  |
| Sudano-Sahelian | 51.162 | 66.125 | -14.963\*\*\* | 67.553 | 63.233 | 4.32\* |
| Sahelian | 48.062 | 7.882 | 40.18\*\*\* | 14.361 | 8.180 | 6.181\*\*\* |
| Sudanese | 0.775 | 25.992 | -25.217\*\*\* | 18.085 | 28.585 | -10.50\*\*\* |
| Type of soil | | | |  |  |  |
| Clay | 30.232 | 30.685 | -0.453 | 27.260 | 33.108 | -5.848\*\*\* |
| Sandy | 31.782 | 44.584 | -12.802\*\*\* | 47.872 | 40.615 | 7.257\*\*\* |
| Laterite | 10.852 | 6.799 | 4.053\* | 6.648 | 7.410 | -0.762 |
| Dryland | 5.426 | 3.61 | 1.816 | 4.255 | 3.368 | 0.887 |
| Stony | 21.705 | 14.32 | 7.385\*\* | 13.962 | 15.495 | -1.533 |
| Cereal yield per hectare | 938.52 | 1291.29 | -352.77\* | 1442.68 | 1137.92 | 304.760\*\*\* |
| (83.323) | (50.810) | (95.582) | (43.666) |

**Notes**: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Standards errors are in brackets.

Source: Author based on PNGT2 data (2016/2017

**Table 4.** Difference test for observable characteristics (continued)

|  |  |  |  |
| --- | --- | --- | --- |
| **Stone cordons** | | | |
| **Variables** | **Adopted** | **Non adopting** | **Difference** |
| Gender (1=man) | 90.647 | 93.523 | -2.876 |
| Agricultural vocational training (1=yes) | 4.316 | 3.753 | 0.563 |
| Education | | | |
| None | 79.856 | 80.885 | 1.029 |
| Primary | 10.071 | 14.259 | -4.188 |
| Secondary | 10.071 | 4.854 | 5.217\*\*\* |
| Age (year) | 50.223 | 47.179 | 3.044\*\* |
| (1.368) | (0.340) |
| Area under cereals (ha) | 2.502 | 2.756 | -0.254 |
| (0.204) | (0.062) |
| household assets (number of people) | 4.054 | 3.822 | -0.231 \*\* |
| (0.206) | (0.053) |
| Non-farm income (FCFA) | 308343 | 318733 | -10390 |
| (31700.94) | (9515.04) |
| Climate zone | | | |
| Sudano-Sahelian | 58.273 | 65.617 | -7.344\* |
| Sahelian | 30.215 | 9.14 | 21.075\*\*\* |
| Sudanese | 0.115 | 0.252 | 1.089\*\*\* |
| Type of soil | | | |
| Clay | 28.057 | 30.871 | -2.814 |
| Sandy | 39.568 | 44.007 | -4.439 |
| Laterite | 4.316 | 7.324 |  |
| Dryland | 7.194 | 3.45 | 3.744\*\* |
| Stony | 20.863 | 14.346 | 6.517\*\* |
| Cereal yield per hectare | 1376.356 | 1256.586 |  |
| (193.255) | (48.961) |

**Notes**: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Standards errors are in brackets.

Source: Author based on PNGT2 data (2016/2017)

# **4- Estimation results and discussion**

The aim of this section is to present and analyses the results of the impact of WSC techniques on cereal productivity.

## **4-1 Tests of econometric robustness**

To test the robustness of the multinomial endogenous treatment effect model, the Hausman test for the irrelevant alternatives hypothesis (IIA) is used. The results of the test show that the null hypothesis of no systematic difference between the coefficients is not violated, since the Chi2 statistic is greater than the 10% threshold with a probability of 1 (see appendix for more details). The model used is therefore appropriate for the analysis.

## **4-2 Adoption determinants**

The results in Table 5 present the determinants of the adoption of zaï, organic manure and stone cordons and their combination in Burkina Faso. Wald statistics were used to assess the overall significance of the multinomial endogenous treatment effect model. The results show that the model is significant overall, as the likelihood ratio test rejects the hypothesis that the coefficients are null at the 1% threshold.

Factors such as climatic zone, gender, off-farm income and number of household assets were found to influence technology adoption in Burkina Faso.

Compared with households living in the Sudano-Sahelian zone, households living in the Sahelian zone are more likely to adopt different soil conservation techniques, whereas households living in the Sudano-Sahelian zone are less likely to adopt different technologies. This can be explained by the fact that this zone is exposed to climatic hazards that force households to improve the fertility of their land by adopting various CES techniques, such as zaï, stone barriers and organic fertilisers. The Sudanese zone, on the other hand, has a climate that is favourable for agriculture in Burkina Faso.

The number of household assets has a positive effect on the probability of adopting organic manure, the probability of adopting stone strips and organic manure, and the probability of adopting all three techniques simultaneously. An increase in the number of workers in the household increases the likelihood of adopting these techniques, as the majority of farms in Burkina Faso are traditional, where labor is mainly family-based. Moreover, the adoption of water and soil conservation techniques is laborious and requires a large labor force. This result is in line with expectations and confirms the findings of Kpadonou et al. (2017).

Compared with clay soils, dryland soils in Burkina Faso have an increased probability of adopting organic manure and stone cordons. These soils are dry, poor in nutrients and poor in water transport. According to Sawadogo (2011), sandy or bare soils are acidic and poor in organic matter, nitrogen, phosphorus and calcium. It is therefore necessary to improve their fertility through water and soil conservation techniques. Similar findings were reported by Abdulai and Huffman (2014).

Off-farm income positively affects the likelihood of households using organic manure and combining zaï and organic manure. A high income enables the household to use and produce high quality manure. Income also enables the household to hire labor to spread organic manure in the field, and to have better access to information and training on organic manure management techniques.

Compared with households with no formal education, households with secondary education in Burkina Faso are more likely to adopt stone cordons and organic manure. This is because training enables farmers to increase their knowledge of how to use stone cordons, gain experience and understand the risks and challenges of soil fertility.

Gender has a negative effect on the likelihood of households adopting zaï and stone cordons. This means that women are more motivated than men are to adopt zaï and stone cordons. Women play an important role in the management of natural resources. Consequently, they are motivated to adopt different techniques to increase their economic autonomy and production.

**Table 5** . Determining the adoption techniques

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Organic manure** | **Zaï** | **Zaï+ Organic manure** | **Stone cordon** | **Stone cordon + Organic manure** | **Stone cordon + Organic manure +zaï** |
| Non farm income | 0.0006\*\*\* | -0.0002 | 0.0007\*\* | -0.00001 | 0.0003 | -0.0005 |
| (0.0001) | (0.0005) | (0.0003) | (0.0004) | (0.000393) | (0.0006) |
| Type of soil (reference: clay) | | | | | | |
| Sandy  Laterite | 0.460\*\*\* | 0.176 | -0.202 | -0.338 | 0.549 | 0.195 |
| (0.149) | (0.460) | (0.348) | (0.361) | (0.394) | (0.487) |
| Dryland | 0.178 | 1.421\*\* | 0.514 | -0.336 | -0.274 | -37.99 |
| (0.265) | (0.569) | (0.518) | (0.669) | (0.820) | (0.0000) |
| Sandy  Laterite | 0.365 | 0.715 | 0.307 | 0.449 | 1.418\*\* | 0.526 |
| (0.354) | (0.874) | (0.712) | (0.707) | (0.661) | (0.945) |
| Dryland | 0.0597 | 0.763 | 0.124 | 0.188 | 0.576 | 0.448 |
| (0.205) | (0.515) | (0.425) | (0.420) | (0.488) | (0.586) |
| Education (reference : none) | | | | | | |
| Primary | 0.183 | 0.219 | 0.254 | -0.363 | -0.496 | 0.539 |
| (0.181) | (0.507) | (0.404) | (0.557) | (0.559) | (0.541) |
| Secondary | -0.208 | 0.468 | 0.224 | 1.356\*\*\* | 0.977\* | 1.030 |
| (0.305) | (0.702) | (0.622) | (0.501) | (0.566) | (0.768) |
| Sex | 0.464 | -1.939\*\*\* | -0.804 | -1.092\*\* | 0.356 | -0.134 |
| (0.293) | (0.525) | (0.525) | (0.469) | (0.785) | (0.867) |
| Age | 0.0004 | -0.0236\* | -0.00551 | 0.0134 | 0.015 | 0.0007 |
| (0.0048) | (0.0139) | (0.0111) | (0.0106) | (0.011) | (0.015) |
| Agricultural training | 0.891\*\*\* | 0.236 | 0.424 | -0.373 | 0.654 | 0.432 |
| (0.333) | (0.886) | (0.702) | (1.073) | (0.692) | (0.867) |
| household assets | 0.041\*\* | 0.0739 | 0.0463 | 0.020 | 0.074\*\* | 0.116\*\* |
| (0.0182) | (0.0453) | (0.0370) | (0.044) | (0.038) | (0.048) |
| Climate zone (reference : Sudano-Sahelian zone) | | | | | | |
| Sahelian | 0.190 | 1.896\*\*\* | 2.032\*\*\* | 1.154\*\*\* | 0.981\*\* | 2.715\*\*\* |
| (0.234) | (0.407) | (0.335) | (0.428) | (0.421) | (0.425) |
| Sudanese | -0.530\*\*\* | -1.824\*\* | -1.170\*\* | -0.241 | -0.960\*\* | -38.48 |
| (0.152) | (0.758) | (0.499) | (0.368) | (0.468) | (0.000) |
| Cereals area | 0.0374 | 0.0614 | -0.0137 | -0.0313 | -0.0131 | -0.201 |
|  | (0.0264) | (0.0745) | (0.0695) | (0.0776) | (0.0709) | (0.130) |
| Constant | -1.819\*\*\* | -1.987\*\* | -2.926\*\*\* | -3.076\*\*\* | -5.522\*\*\* | -4.829\*\*\* |
|  | (0.385) | (0.852) | (0.762) | (0.738) | (1.008) | (1.151) |
| Wald test | 295.49 |  |  |  |  |  |
| Observations | 1773 | 1773 | 1773 | 1773 | 1773 | 1773 |

**Notes**: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. Standards errors are in brackets.

**Source**: Author based on PNGT2 data (2016/2017)

## **4-3 Interpreting the effects of water and soil conservation techniques on cereal productivity**

Table 6 shows the results of the multinomial endogenous treatment effect model. The results indicate the presence of unobservable bias, as the values of the lambda parameter, which measures the correlation between treatment assignment errors (joint adoption of zaï and organic fertiliser, joint adoption of organic fertiliser and stone barriers) and outcome errors (cereal productivity), are statistically significant. This justifies the use of the multinomial endogenous treatment effect model to control for the different biases.

After controlling for unobservable bias, it was found that households using zaï and organic fertiliser together, and those using a combination of stone cordons and organic fertiliser, had higher cereal productivity than those using organic fertiliser, zaï and stone cordons alone. The gain in cereal productivity is estimated at 355.1 kg/ha when the household uses only organic fertiliser, 571.8 kg/ha when it combines zaï and organic fertiliser and 528.1 kg/ha when it uses both organic fertiliser and stone cordons. These results can be explained by the complementary relationship that exists between the different water and soil conservation techniques. In fact, the diversification of SWC techniques enables households to cope with several constraints to improving production, such as runoff speed and runoff. Zaï and stone barriers improve cereal productivity when combined with organic fertiliser. The zaï captures rainwater and nutrients; the organic manure enriches the soil and promotes better nutrient uptake by plants; the stone strips reduce run-off and erosion. The work of Soumana et al (2022) provides ample evidence of the impact of such synergistic soil conservation techniques in Niger.

The results also show that rainfall has a positive effect on cereal productivity in Burkina Faso. This means that an increase in rainfall leads to an increase in cereal productivity. This result can be explained by the fact that good rainfall reduces water stress on crops and improves their growth. Rainfall facilitates the decomposition of organic matter and allows the dissolution and transport of essential plant nutrients.

**Table 6**. Impact of SWC adoption on cereal productivity

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Variables** | **Organic manure** | **Zaï** | **Organic manure+zaï** | **Stone cordon** | **Stone cordons+Organic manure** | **Productivité céréalière** |
| Organic manure |  |  |  |  |  | 355.1\*\*\* |
|  |  |  |  |  | (109.2) |
| Zaï |  |  |  |  |  | 286.8 |
|  |  |  |  |  | (263.2) |
| Organic manure+zaï |  |  |  |  |  | 571.8\*\*\* |
|  |  |  |  |  | (218.2) |
| Stone cordon |  |  |  |  |  | 161.0 |
|  |  |  |  |  | (234.3) |
| Stone cordons+Organic manure |  |  |  |  |  | 528.1\*\* |
|  |  |  |  |  | (242.6) |
| Revenu non agricole | 0.0006\*\*\* | -0.0002 | 0.0007\*\* | -0.00005 | 0.0003 | 0.009 |
| (0.0001) | (0.0005) | (0.0003) | (0.0004) | (0.0003) | (0.102) |
| Type of soil (reference: clay) | | | | | | |
| Sandy | 0.456\*\*\* | 0.0716 | -0.157 | -0.304 | 0.552 | 68.34 |
| (0.150) | (0.459) | (0.350) | (0.360) | (0.395) | (90.14) |
| Laterite | 0.182 | 1.369\*\* | 0.580 | -0.332 | -0.215 | 200.0 |
| (0.265) | (0.578) | (0.518) | (0.672) | (0.811) | (157.6) |
| Dryland | 0.330 | 0.747 | 0.318 | 0.472 | 1.335\*\* | -296.3 |
| (0.356) | (0.872) | (0.720) | (0.720) | (0.676) | (210.0) |
| Stony | 0.0487 | 0.784 | 0.155 | 0.172 | 0.528 | -74.23 |
| (0.206) | (0.514) | (0.429) | (0.424) | (0.490) | (120.5) |
| Household size | 0.0434\*\* | 0.0740 | 0.0474 | 0.0245 | 0.0687\* | -8.696 |
| (0.0183) | (0.0458) | (0.0372) | (0.0447) | (0.0378) | (10.30) |
| Education (référence : no) | | | | | | |
| Primary | 0.176 | 0.289 | 0.253 | -0.333 | -0.496 | 197.0\* |
| (0.182) | (0.510) | (0.407) | (0.559) | (0.567) | (111.6) |
| Secondary | -0.207 | 0.455 | 0.131 | 1.361\*\*\* | 1.030\* | -2.744 |
| (0.306) | (0.706) | (0.635) | (0.501) | (0.566) | (175.2) |
| Agricultural training | 1.049\*\*\* | 0.466 | 0.0946 | -0.702 | 0.428 | 303.5 |
| (0.359) | (0.954) | (0.772) | (1.116) | (0.788) | (201.0) |
| gender | 0.550\* | -2.04\*\*\* | -0.897\* | -1.183\*\* | 0.343 | -0.386 |
| (0.298) | (0.535) | (0.530) | (0.468) | (0.785) | (161.6) |
| Age | 0.000161 | -0.0229 | -0.00632 | 0.0155 | 0.0145 | 0.148 |
| (0.00481) | (0.0140) | (0.0111) | (0.0108) | (0.0116) | (2.877) |
| Rainfall | 0.0004 | -0.0016 | -0.0003 | -0.0011 | 0.0009 | 0.771\*\*\* |
| (0.000453) | (0.00131) | (0.00107) | (0.00112) | (0.00110) | (0.247) |
| Agricultural extension service | -0.316 | -0.926 | 0.516 | 0.501 | 0.295 |  |
| (0.296) | (1.122) | (0.564) | (0.603) | (0.666) |  |
| Climatic zone (reference: Sudano-Sahelian) | | | | | | |
| Sahélian | 0.249 | 1.799\*\*\* | 2.041\*\*\* | 1.063\*\* | 1.150\*\*\* |  |
| (0.240) | (0.417) | (0.349) | (0.434) | (0.443) |  |
| Sudanese | -0.573\*\*\* | -1.590\*\* | -1.095\*\* | -0.108 | -1.044\*\* |  |
| (0.164) | (0.785) | (0.520) | (0.402) | (0.484) |  |
| Area under cereals | 0.0326 | 0.0556 | -0.0286 | -0.0533 | -0.0133 |  |
| (0.0270) | (0.0753) | (0.0720) | (0.0813) | (0.0725) |  |
| Constant | -2.364\*\*\* | -0.216 | -2.450\* | -1.903 | -6.468\*\*\* | 230.5 |
| (0.602) | (1.576) | (1.338) | (1.364) | (1.543) | (341.4) |
| Lnsigma |  |  |  |  |  | 7.342\*\*\* |
|  |  |  |  |  | (0.019) |
| Lambda\_Organic manure |  |  |  |  |  | -157.6\* |
|  |  |  |  |  | (85.55) |
| Lambda\_zaï |  |  |  |  |  | 62.92 |
|  |  |  |  |  | (76.88) |
| Lambda\_zaï+Organic manure |  |  |  |  |  | -224.5\*\*\* |
|  |  |  |  |  | (81.08) |
| lambda\_Stone cordon |  |  |  |  |  | -21.78 |
|  |  |  |  |  | (89.86) |
| Lambda\_Stone cordon+manure |  |  |  |  |  | -191.6\*\*\* |
|  |  |  |  |  | (74.34) |
| Wald chi2(97) |  |  |  |  |  | 270.81 |
| Observations |  |  |  |  |  | 1741 |

**Notes**: \*\*\* p<0.01, \*\* p<0.05, \* p<0.1. standards errors in brackets.

**Source**: Author based on PNGT2 data (2016/2017)

# **5- Conclusion and political economics implications**

The development of the agricultural sector remains at the center of current economic debates. In developing countries such as Burkina Faso, agriculture faces several challenges, including declining soil fertility and climatic hazards. In the face of these problems, the adoption of water and soil conservation techniques could be a solution to sustainably increase agricultural productivity and reduce food insecurity.

The aim of this research is to analyse the impact of WSC techniques on cereal productivity in Burkina Faso. The multinomial endogenous treatment effect model is used. The statistical and econometric analyses are based on secondary data collected in the PNGT2 survey of 1741 households.

The results revealed that the joint adoption of zaï and organic manure and the combination of stone cordons and organic manure resulted in greater cereal productivity gains than did the individual adoption of the different techniques. Furthermore, the use of organic manure improves cereal yields, whereas zaï and stone cordons do not affect cereal productivity in Burkina Faso.

Given the importance of cereals in the socioeconomic life of the rural population and in light of our results, improving agricultural productivity in Burkina Faso requires the popularisation of water and soil conservation techniques. In this sense, any policy aimed at increasing cereal productivity must promote soil fertility management by encouraging the acquisition of the equipment needed to implement various CES techniques, particularly in the Sahelian zone of Burkina Faso. Agricultural policies should ensure that farmers understand the characteristics and implementation standards of various CES techniques through vocational training. This will enable households to diversify their different techniques to achieve better yields. In addition, the use of organic manure is necessary to improve the effectiveness of zaï and stone cordons in Burkina Faso.

This research has shown that the diversification of soil conservation techniques contributes more to improving cereal yields in Burkina Faso than does individual adoption. However, it does not consider the time dimension or all techniques due to a lack of data. The use of time series data for future research would yield very interesting results.

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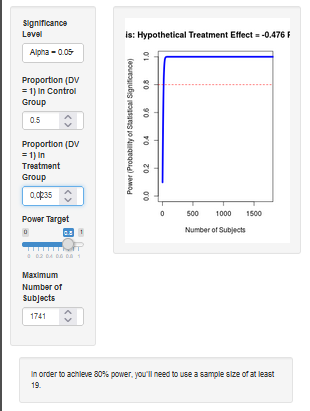
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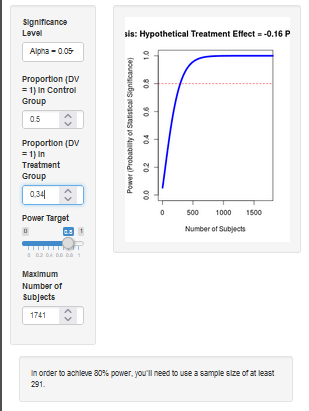
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Appendix 1: Test of independence of irrelevant alternatives



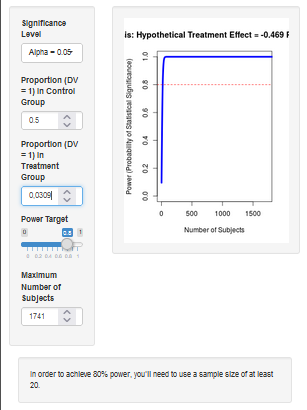
Appendix 2: Calculation of statistical power to determine the minimum detectable effect

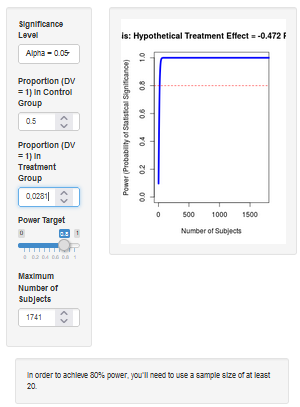
Zaï adoption (2.35%) organic manure adoption (34%)



Organic manure and stone cordons adopted together (2.81%)

Stone cordons adoption (3.09%)





Organic manure and zaï adopted together (3.6%)

