CLIMATE CHANGE EFFECTS ON POVERTY AMONG CEREAL FARMERS IN MALI

EFFETS DES CHANGEMENTS CLIMATIQUES SUR LA PAUVRETÉ DES PRODUCTEURS DE CÉRÉALES AU MALI

Moussa MACALOU
Institut d'Economie Rural (ECOFIL/IER)
macaloumoussa29@yahoo.fr

Mahamadou Bassirou TANGARA
Faculté des Sciences Economiques et de Gestion de Bamako (USSGB/FSEG)
Pilot African Potsgraduate Academy (PAPA) Université Goethe, Point Sud
mb.t75@mesrs.ml

Moussa DIALLO
Faculté des Sciences Economiques et de Gestion de Bamako (USSGB/FSEG)
moussaballa02@gmail.com

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Abstract

The vulnerability of poor countries is explained by their dependency on natural goods and services as well as their limited adaptive capacity to climate change. The farm households are heterogeneous and therefore their ability to adapt to climate change is different. This study analyses the effects of climate change on poverty among cereals farmers in Mali by accounting for adaptation measures using an OLS and instrumental variable method. The study used secondary data covering the cereal production (millet, maize, sorghum, and rice) for the regions of Kayes, Koulikoro, Sikasso, Segou, Mopti, and Tombouctou from 1987 to 2017. The results show that among the cereal farmers, poverty increases as a result of the impact of climate change in the region of Kayes, Koulikoro, Sikasso, and Mopti compared to the region of Segou. The results also show that an increase in the cereal output (sorghum, millet, maize, and rice) and population leads to decrease poverty.

Keyword: Climate change, cereal farmers, Mali, poverty

Résumé

La vulnérabilité des pays pauvres s'explique par leur dépendance aux biens et services naturels ainsi que par leur capacité d'adaptation limitée au changement climatique. Les ménages agricoles sont hétérogènes et donc leur capacité d'adaptation au changement climatique est différente. Cette étude analyse les effets du changement climatique sur la pauvreté des producteurs de céréales au Mali en tenant compte des mesures d'adaptation en utilisant une méthode de MCO et des variables instrumentales. L'étude a utilisé des données secondaires couvrant la période de 1987 à 2017 concernant la production céréalière (millet, maïs, sorgho et riz) des régions de Kayes, Koulikoro, Sikasso, Ségou, Mopti et Tombouctou. Les résultats montrent que chez les producteurs de céréales, la pauvreté augmente suite à l'impact du changement climatique dans les régions de Kayes, Koulikoro, Sikasso, et Mopti par rapport à la région de Ségou. Les résultats montrent également qu'une augmentation de la production céréalière (sorgho, mil, maïs et riz) et de la population entraîne une diminution de la pauvreté.

***Mots clé** : Changement climatique, pauvreté, producteurs de céréales, Mali*

Introduction

Considerable progress has been made in reducing poverty over the past two decades. The poverty rate went from 42% to less than 15% from 1995 to 2015 (Hallegatte et al., 2014). However, humanity is facing unequivocal climate warming (IPCC, 2007). Global temperatures on average have increased by 0.85°C from 1986 to 2012 and estimates indicate further increases of about 1.5°C by 2050 (AGRA, 2014). The resulting climate change is likely to affect agricultural productivity.

In developing countries, climate related-disturbances threaten to intensify poverty, food insecurity and unsustainable development (IPCC, 2007). Africa region is seen to be the most affected by the effects of climate change due to the fragility of their economy. There is an advocate for the second green revolution in precarious agricultural regions such as sub-Saharan Africa, which is explained by smallholder farmers' vulnerability to climate-related risks in these regions (Hansen, et al. 2018). As a result, the prevalence of poverty and food insecurity is high in these regions. The vulnerability of poor countries is explained by their dependency on natural goods and services as well as their limited adaptive capacity to climate change. The farm households are heterogenous and therefore their ability to adapt to climate change is different. The poor households appear to be more affected by the impacts of climate change relative to rich households, which would increase the incidence of poverty in terms of severity and persistence in developing countries (Skoufias et al., 2011). Climate change is seen as a serious challenge for poverty alleviation efforts in that context. The fight against climate change is crucial to eradicating poverty (Gutierrez et al., 2014). The knowledge and the way rural poor might be affected is required to understand the potential impacts of climate (Chen et al., 2015). The decline in agricultural productivity resulting from climate change is likely to affect differently net food producer households compared to those who are net food buyers (Skoufias et al., 2011).

Agriculture constitutes the main activity in Mali. The analysis of the contribution of economic sectors to GDP shows that the Malian economy is dominated by the primary sector followed by the tertiary sector with a slight difference according to the years (INSTAT, 2018). The primary sector's share of GDP varies between 38% and 42% (INSTAT, 2018). For example, in 2012, the primary sector has contributed 42.2% of GDP compared with 35.53% for the tertiary sector and 22.44% for the secondary sector while the sectoral contribution to GDP, in 2016 was 40.9% for the primary sector which was slightly higher than that of the tertiary sector (40.26%) and more than twice that of the secondary sector (18.85%) (INSTAT, 2018). Agriculture (food and export agriculture) and livestock dominate the primary sector. During the period 1999 to 2013, Agriculture accounted for about 43% of the sector's GDP, livestock represented 39%, and the other branches, namely fishing and forestry, accounted for 18% (INSTAT, 2018).

Malian population living below the poverty line of US $1.9 a day (measured at 2011 international prices adjusted for purchasing power parity) was estimated at about 49.7% in 2009 (World Bank, 2019). During the same period, the poverty gap ratio was estimated at about 15.4%. This ratio represents the depth of poverty; it captures the distance between the poor on average and the poverty line. According to the World Bank, 42.7% of Malians lived in extreme poverty in 2017. Poverty is concentrated in rural areas (90% of all poor) and in the south of the country. The majority of that portion of the population of Mali affected by poverty depends on agriculture as their major livelihood. The government relied on strategies such as the provision of subsidised agricultural inputs, the training to build capacity of smallholder farmers, and increasing farmers' access to credit among others to alleviate poverty. Despite these efforts, the challenge to improve the livelihoods of these poor people is increasing. This challenge may be worsened by climate change. Therefore, investigating the effects of climate change on poverty in Mali becomes relevant to guide policy makers and farmers.

Based on our knowledge, only Assunção & Feres (2009) have analysed the effects of climate change on poverty by considering the adaptation strategies. They relied only on labor mobility as an adaptation strategy. The adaptation strategies may differ from one region to another within the country, based on the magnitude affecting each region and the adaptation options available in each region for farmers. For example, some regions may have irrigation facilities, while others may rely on improving crop varieties. In addition to the mobility of labour, the unobservable regional specific effects may be a proxy in considering adaptation strategies to climate change. Therefore, this study aims to analyse the effects of climate change on poverty among cereal farmers in Mali by accounting for adaptation measures. The study uses unobservable regional specific effects in addition to the mobility of labour. Specifically, the present study seeks to analyse the effects of climate change on poverty among cereal farmers namely millet, sorghum, maize, and rice in Mali.

The structure of the remaining of this paper is as follows. The materials and methods are described in section 2; the results are discussed in section 3; the conclusion is drawn and the policy recommendations are made in section 4.

1. Materials and methods

1.1. Method of analysis

Following Assunção & Feres (2009), the study uses ordinary least squares (OLS) to estimate the effects of climate change on poverty status of cereal farmers in Mali. The cereals of interest are millet, sorghum, maize, and rice. The specification of the model accounts for the adaptation strategies through the mobility of labour (population) and regional differences. For a given cereal, the model is specified as follows:

$$P_{it} = \alpha_0 + \alpha_1 lnN_{it} + \alpha_2 lnY_{it} + \omega_i \sum_{i=1}^{5} Reg_i + \varepsilon_{it} \qquad (1)$$

Where P_{it} is the share of region i on the national poor at time t,α's is a vector of parameters to be estimated. lnN_{it} represents the population of region i at time t, lnY_{it} is the logarithm of the agricultural output of region i during time t, Reg_i is a dummy for region i which accounts for the regional differences, ω is the coefficient associated to the dummy for region i, trend accounts for technological change, and ε_{it} is the error term. The study considers the mobility of labour since the number of poor at both national and region levels have included both rural and urban. The regional differences, time trend for technological change and mobility of labour across sectors (agricultural sector and other parts of the economy) and areas allows cereal farmers to adapt to climate variation.

Y_{it} is correlated with the error term ε_{it}, the endogeneity of Y_{it} makes the estimate of equation (1) inconsistent. To correct the endogeneity issue, the study uses an instrumental variable estimation. The instruments used for Y_{it} are land, fertilizer, labour, rainfall, maximum temperature, minimum temperature, and time trend accounting for technological change. For a given cereal, the empirical specification of the instrumental variable method is expressed as follows:

$$lnY_{it} = \beta_0 + \beta_1 lnland_{it} + \beta_2 lnorgfert_{it} + \beta_3 lninorgfert_{it} + \beta_4 lnlabour_{it} + \beta_5 lnrain_{it} + \beta_6 lnmintemp_{it} + \beta_7 maxtemp_{it} + \beta_8 trend + \mu_{it} \qquad (2)$$

1.2. Data and description of the variables

1.2.1. Data

The data used in this analysis was from various sources and included climate and non-climate data. The non-climate data included the agricultural, demographic, and poverty data. The agricultural data was obtained from the planning and statistical unit through the Agricultural survey of conjuncture. The Agricultural survey of conjuncture is an annual survey, which covers all the regions of Mali. The agricultural data used in this analysis cover the cereal production (millet, maize, sorghum, and rice) for the regions of Kayes, Koulikoro, Sikasso, Segou, Mopti, and Tombouctou from 1987 to 2017. The variables covered by the agricultural data are production, land, labour, inorganic, and organic fertilizer. The demographic and poverty data were obtained from the World Bank. The climate data was obtained from the meteorological of Mali and encompassed the average annual rainfall and temperature.

1.2.2. Descriptive statistic

- **Input poverty and climate variables**

The descriptive statistic is summarised in table 1. It includes climate variables (rainfall, minimum temperature, maximum) and non-climate variables (organic fertilizer, Inorganic fertilizer, and the national poverty share per region) for five cereal production regions (Kayes, Koulikoro, Sikasso, Segou, and Mopti) from 1987 to 2014.

The table 1 shows that, on average, Mopti region uses more organic fertilizer per ha while Sikasso region uses more inorganic fertilizer compared to the other regions. Mali is one of the countries where agricultural production relies on intensive use of fertilizer. The intensive use of fertilizer can be a possible route to improve agricultural productivity. On average, Segou region has the highest labour force compared to the other regions.

Table 1: Input poverty and climate variables

Regions	Kayes	Koulikoro	Sikasso	Segou	Mopti
Organic fertilizer (kg/ha)	56 (12)	976 (445)	1044 (321)	67.31 (7.76)	1183 (417)
Inorganic fertilizer (ha/ha)	52.42 (25.78)	93.19 (491)	151.25 (68.5)	105.13 (62.58)	60.52 (21.8)
Labour	968567.9 (601778.5)	978826 (638197.9)	919589.4 (910957.2)	2082667 (619543.6)	582203.8 (630008.5)
Rainfall (mm)	626.08 (167.51)	761.94 (258.76)	1160.1 (162.78)	652.56 (124.41)	497.03 (129.65)
Maxi temperature (°C)	34.64 (0.77)	35.13 (1.04)	30.79 (1.44)	33.96 (1.18)	32.86 (4.71)
Min temperature (°C)	24.23 (0.50)	22.57 (1.82)	21.64 (1.00)	23.41 (0.44)	22.63 (3.19)
Poverty share (%)	11.99	14.28	15.78	13.39	12.42
Observation	27	27	27	27	27

Source: Author's calculations using data from planning and statistical unit (CPS)

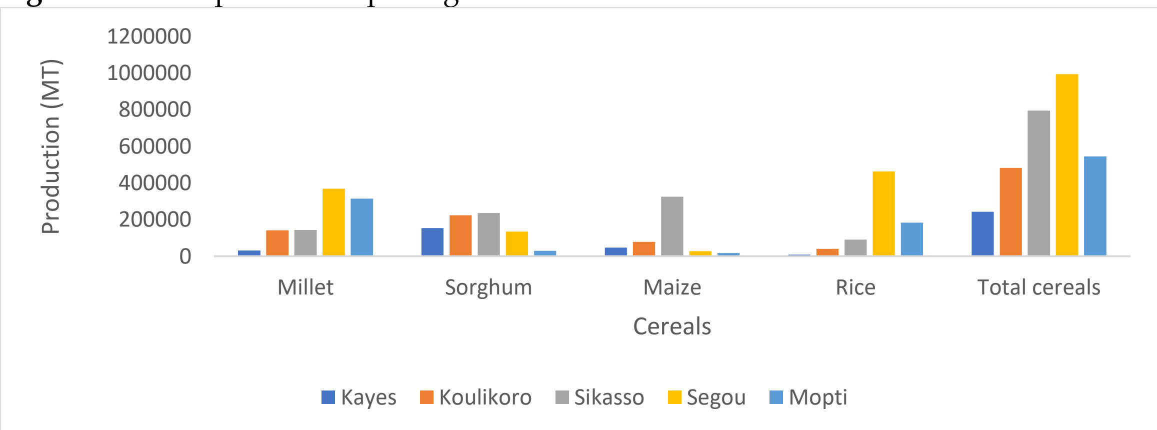
The rainfall, the maximum temperature and minimum temperature were used as climate variables in this study. From 1987 to 2014, on average, table shows that Sikasso region received more rainfall (1160.1 mm) compared to the other regions. Sikasso region is part of Sodano-Sahelian zone with a range of rainfall varying between 700 and 1200 mm per year spread over 4 months (June to October) with an average of 60 to 80 days of rainfall occurrence. The maximum temperature is above 30°C while the minimum temperature is above 20°C for all the regions showing that Mali is a warmer country.

The national poverty share over the regions have shown that Sikasso region has the highest rate of poverty head counts. Poverty is a rather complex concept that is characterized by a situation of incapacity, hardship, exclusion and insufficient income in which an individual finds himself.

- **Cereal production**

Cereal production per region is depicted in Figure1. On average, it shows that Segou region has the highest production of millet and rice 369084 mt and 463451 mt respectively while, the region of Sikasso has production of Sorghum and Maize with 235545 mt and 325516 mt, respectively. For the total cereal production, Segou region has the highest cereal production (994846 mt) followed by Sikasso region (794925 mt)

Figure 1: Cereal production per region

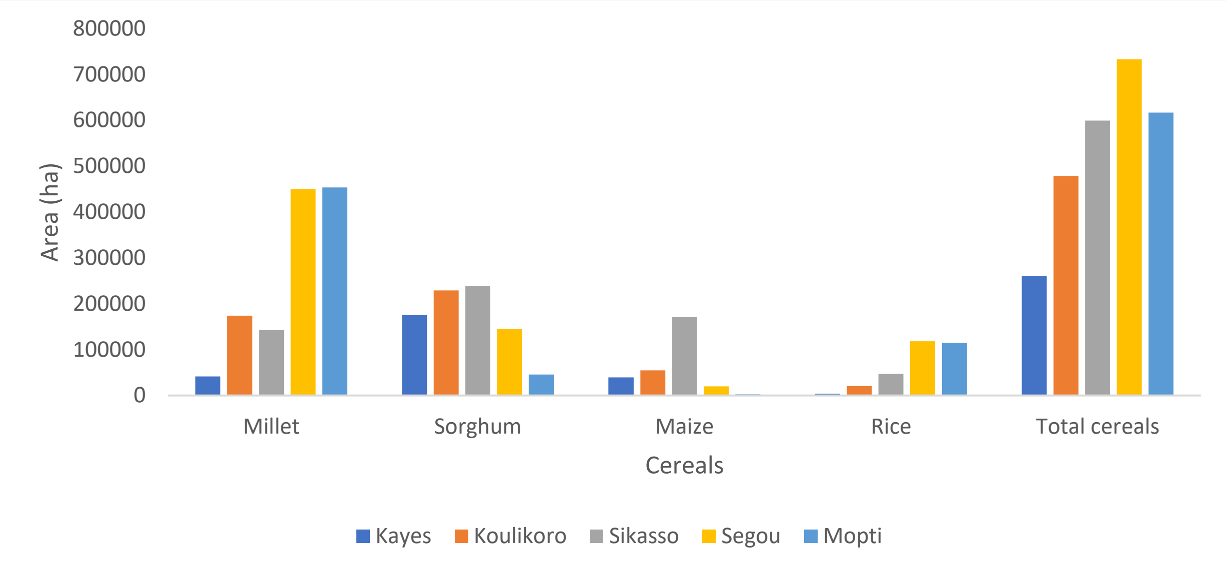


Source: Author's calculations using data from planning and statistical unit (CPS)

- **Area allocated to cereal production**

Area allocated to cereal production is presented in Figure2. It shows that, on average, Segou region allocates more land to Millet and Rice production 449820 ha and 118039 ha, respectively, while, the region of Sikasso allocates more area to Sorghum and Maize production 238698 ha and171055 ha, respectively. Segou region allocates more land (732748 ha) to cereal production compared to the other regions.

Figure 2: Figure1: Area allocated to cereal production per region



Source: Author's calculations using data from planning and statistical unit (CPS)

- **Study area**

Cereals are grown in all the regions of Mali. The region of Gao and Kidal were not covered by this study due to the missing values for these two regions which are explained by security issues. The study covers six cereal production regions of Mali namely Kayes, Koulikoro, Sikasso, Segou, Mopti, and Tombouctou.

2. Results and discussion

2.1. Results of the effects of climate variability on cereals production

This section presents the effects of climate variability on cereals production (first stage). For all the models (sorghum, millet, maize, and rice), the results indicate that the probability associated to F-statistics is statistically significant at one percent. Which means that globally the explanatory variables explain the dependent variable (Table1), in fact all the models are globally significant. The results also indicate that the overall R-squared are 0.1, 0.82, 0.33, and 0.68 for the model of sorghum, millet, maize, and rice, respectively. This means that 10%, 82%, 33%, and 68% of the variation of the dependent variable is explained by the variation of the explanatory variables for the model of sorghum, millet, maize, and rice, respectively.

Table 2: effects of climate variability on cereals production

VARIABLES	Sorghum	Millet	Maize	Rice
Land	-1.34e-06	1.028***	0.733***	1.160***
	(8.85e-07)	(0.0440)	(0.171)	(0.125)
Organic fertilizer	0.0282	0.00241	-0.0408	-0.174*
	(0.0358)	(0.0248)	(0.110)	(0.105)

Inorganic fertilizer	0.999***	-	0.134*	-0.258***
	(0.121)	-	(0.0737)	(0.0652)
Labor	0.846***	0.501***	0.995*	2.040***
	(0.219)	(0.142)	(0.601)	(0.337)
Rainfall	0.196**	0.170***	0.138	0.177
	(0.0811)	(0.0579)	(0.204)	(0.138)
Maximum temperature	0.441	-0.829*	0.151	-1.434
	(0.637)	(0.497)	(1.487)	(1.102)
Minimum temperature	-0.173	0.863*	1.130	1.090
	(0.628)	(0.488)	(1.453)	(1.061)
Trend	-0.00393***	-0.00116	-0.00648	0.00308
	(0.00119)	(0.00117)	(0.00429)	(0.00486)
Constant	-14.80***	-8.557***	-16.90**	-26.00***
	(3.314)	(1.971)	(7.300)	(4.862)
Observations	135	135	135	135
Number of regions	5	5	5	5
F(7,123)	6.91	82.96	6.91	42.81
Prob >F	0.000	0.000	0.000	0.000
R-sq overall	0.095	0.817	0.326	0.684

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations using data from planning and statistical unit (CPS)

The results of the effects of climate variability on cereals production are presented in Table1. The results show that rainfall positively influences output of sorghum and millet while maximum temperature negatively influences output of millet. This means that output of sorghum and millet increases as a result of an increase in rainfall while output of millet decreases as a result of an increase in maximum temperature. It is evident that frequent extreme events may lower long-term yields by straight damaging crops at specific developmental stages. Especially such as temperature thresholds during flowering, otherwise by making the timing of farm preparation more difficult, thus decreasing the efficiency of farm fertility (Porter and Semenov, 2005; Antle et al, 2004). This situation can be understood because looking at the high temperature of the Sahel it could damage the crops during some stages of their development process.

The positive link between the output of sorghum and millet and rain could be explained by the fact that farmers in the study area are smallholder farmers who rely on rainfall to produce cereals. For instance, they wait for the installation of the first rains before plowing their fields because they have less mechanical equipment capable to plow the dry soil. The inverse relationship between maximum temperature and millet output could be explained by the fact that farmers are less efficient (tired and exhausted) when they work under warmer temperature. The results also show that an increase in land leads to increase output of millet, maize, and rice. Most of the agricultural technologies are costly to farmers in the study area, which result to reduce their adoption capability of those technologies. Farmers allocated more land to cereal production to increase their cereal output.

An increase in the application rate of inorganic fertilizer leads to increase output of sorghum and maize and decrease output of rice indicate the results. The positive link between inorganic fertilizer and output of sorghum and maize could be explained by the fact that inorganic fertilizer brings nutrients to the plant, which increase the output. The inverse relationship between inorganic fertilizer, organic fertilizer and output of rice can be understood because rice is mainly grown in lowland in Mali, which does not have an appropriate drainage infrastructure. As a result, the leaching washes the nutrients of inorganic fertilizer away. The factor labour had positive significant effect on all crops output, which is easy to understand because the agricultural sector is still suffering from the lack of mechanization. There is no mechanization industry of agriculture in Mali that can boost agriculture production.

2.2. Results of the effect of agricultural output on poverty

The results of the effect of agricultural output on poverty are presented in table2. For all the crops (sorghum, millet, maize, and rice), the results indicate that the probability associated to chi2 is statistically significant at one percent meaning that globally the explanatory variables explain the dependent variable (Table2). The results also indicate that the overall R-squared is 0.63, 0.67, 0.58, and 0.63 for the model of sorghum, millet, maize, and rice, respectively. This means that 63%, 67%, 58%, and 63% of the variation of the poverty is explained by the variation of the explanatory variables for the model of sorghum, millet, maize, and rice, respectively.

The results of the effect of agricultural output on poverty show that an increase in all the cereal output (sorghum, millet, maize, and rice) leads to decrease poverty. This result could be explained by the fact farmers in the study area rely on cereals as staple food and source of income as well. The negative impact of climate change on agricultural productivity leads to raise food prices due to the gap between the demand and the supply of food in the market (Skoufias et al., 2011). The income of agricultural households will increase as a result of that increase in food prices.

Table 3: Results of the effect of agricultural output on poverty

VARIABLES	Sorghum	Millet	Maize	Rice
Output	-0.00614*	-0.00902***	-0.00547**	-0.0125***
	(0.00373)	(0.00211)	(0.00249)	(0.00208)
Population	-0.00253*	-0.00180	-0.00274**	0.00459**
	(0.00146)	(0.00121)	(0.00137)	(0.00186)
Kayes region	0.0256***	0.0377***	0.0257***	0.0482***
	(0.00335)	(0.00443)	(0.00343)	(0.00518)
Koulikoro region	0.0398***	0.0521***	0.0474***	0.0775***
	(0.00352)	(0.00458)	(0.00578)	(0.00745)
Sikasso region	0.0158***	0.0396***	0.0138***	0.0685***
	(0.00354)	(0.00591)	(0.00398)	(0.00904)
Mopti region	-0.00788	0.0250***	-0.0158*	0.0534***
	(0.00657)	(0.00623)	(0.00860)	(0.00921)
Constant	0.227***	0.236***	0.215***	0.160***
	(0.0360)	(0.0208)	(0.0253)	(0.0163)
Observations	135	135	135	135
Number of regions	5	5	5	5
R-sq overall	0.63	0.67	0.58	0.63
Chi2	216.63	257.95	192.02	242.15
Prob >chi2	0.0000	0.0000	0.0000	0.0000

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

Source: Author's calculations using data from planning and statistical unit (CPS)

The results of the instrumental variable model (IV) also indicate that an increase in population leads to a reduction in poverty. This result could be explained by the fact in the face of climate change; farmers adopt adaptation strategies such as migration of the population. The extend of the adaptation strategies determines the extend of the impact of climate change on poverty (Skoufias et al., 2011). Assuncao and Chein (2016) also found that labour mobility reduces the negative impact of climate change on poverty.

The results also show that among the cereal farmers, the poverty increases as a result of the impact of climate change in the region of Kayes, Koulikoro, Sikasso, and Mopti compared to the region of Segou. This means that the geographical location plays a key role in determining the impact of climate change on poverty. Assuncao and Chein (2016) also found that the impact of climate change on poverty differs across the municipalities.

Conclusion

Much attention has not been given to the effects of climate change on poverty while considering adaptation strategies by previous studies. This paper contributes to the empirical literature in this field by investigating the effects of climate change on poverty among cereal farmers in Mali by accounting for adaptation measures using an OLS and instrumental variable method on secondary data collected from various source. The results suggest that climate change affects poverty and the extend differs from one region to another. Through adaptation strategies, the increase in cereal output leads to reduce poverty level. Therefore, the study recommends cereal farmers to intensify adaptation measures to alleviate poverty. Regarding to the multifaceted aspect of poverty and the complexity of climate change therefore, for future research, it will be important to take account other type of poverty and a large disaggregated variables of climate change. It is recognized that climate is dynamic and highly varies from place-to-place.

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