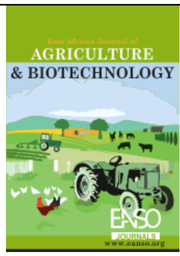


East African Journal of Agriculture and Biotechnology
eajab.eanso.org
Volume 7, Issue 1, 2024
p-ISSN: 2707-4293 | e-ISSN: 2707-4307
Title DOI: https://doi.org/10.37284/2707-4307

EANSO
EAST AFRICAN NATURE & SCIENCE ORGANIZATION

Original Article

Impact of Agroecological Innovations on Agricultural Production and the Environment in the Foothills of Mumirwa, Burundi

Dismas Manirakiza[1], Ingrid Fromm[2], Théogène Nsengiyumva[3] & Hypax Nzoyikunda[3]*

[1] Bujumbura International University, P. O. Box 20 Bujumbura, Burundi.
[2] Bern University of Applied Sciences, 36, Bern, Bern, Switzerland.
[3] Burundi National University, Blvd. de l'UPRONA Bujumbura 1550. Burundi.
* Author for Correspondence ORCID ID: https://orcid.org/0009-0009-6751-5635; Email: dismasmanirakiza77@gmail.com

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

Date Published:

11 March 2024

Keywords:

Agroecology, Innovation, Impact, Production, Environment.

ABSTRACT

Agriculture is an important pillar of the national economy of Burundi. The sector contributes more than 40 % of gross domestic product (GDP) and employs 90 % of the population. The main challenges facing the sector include soil degradation, loss of biodiversity, water contamination, pesticide residues, use of genetically modified organisms and participation in climate change. Faced with such constraints, the Burundian farmers experience new modes of production and consumption such as the development of agroecological farms (crop association, crop rotation, agroforestry, anti-erosion ditches) and the use of biofertilizers and biopesticides. This study aims to analyse the impact of agro-ecological innovations on agricultural production and environment in Mumirwa region, especially in three communes of Bubanza province (Bubanza, Musigati and Rugazi). The study approach consisted of surveys conducted on two samples (members of cooperatives and non-members), focus groups, individual interviews and field visits. The ordinary least squares method and comparative approach between the two samples (treatment sample and comparison sample) were used to analyse the impact on production and environment, especially on soil fertility. We referred to the ISABU laboratory (Higher Agronomic Institute of Burundi) results of the soil samples brought by ADISCO NGO before and after planting the beans using organic manure on the one hand and chemical fertilizers on the other. The results showed that agro-ecological practices positively impact agricultural production and improve soil fertility. After one year of adoption, bean production increased by 21%. The analysis of the soil samples indicate that the combination of agro-ecological practices improves the soil's chemical characteristics, contributing to increased productivity. This could be explained by the fact that the development of agro-ecological farms and biofertilizers promote the sedimentation of particles of organic matter from runoff water and organic manure.

APA CITATION

Manirakiza, D., Fromm, I., Nsengiyumva, T. & Nzoyikunda, H. (2024). Impact of Agroecological Innovations on Agricultural Production and the Environment in the Foothills of Mumirwa, Burundi. *East African Journal of Agriculture and Biotechnology*, *7*(1), 140-147. https://doi.org/10.37284/eajab.7.1.1815

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

CHICAGO CITATION

Manirakiza, Dismas, Ingrid Fromm, Théogène Nsengiyumva and Hypax Nzoyikunda. 2024. "Impact of Agroecological Innovations on Agricultural Production and the Environment in the Foothills of Mumirwa, Burundi". *East African Journal of Agriculture and Biotechnology* 7 (1), 140-147. https://doi.org/10.37284/eajab.7.1.1815.

HARVARD CITATION

Manirakiza, D., Fromm, I., Nsengiyumva, T. & Nzoyikunda, H. (2024) "Impact of Agroecological Innovations on Agricultural Production and the Environment in the Foothills of Mumirwa, Burundi", *East African Journal of Agriculture and Biotechnology*, 7(1), pp. 140-147. doi: 10.37284/eajab.7.1.1815.

IEEE CITATION

D. Manirakiza, I. Fromm, T. Nsengiyumva & H. Nzoyikunda "Impact of Agroecological Innovations on Agricultural Production and the Environment in the Foothills of Mumirwa, Burundi", *EAJAB*, vol. 7, no. 1, pp. 140-147, Mar. 2024.

MLA CITATION

Manirakiza, Dismas, Ingrid Fromm, Théogène Nsengiyumva & Hypax Nzoyikunda. "Impact of Agroecological Innovations on Agricultural Production and the Environment in the Foothills of Mumirwa, Burundi". *East African Journal of Agriculture and Biotechnology*, Vol. 7, no. 1, Mar. 2024, pp. 140-147, doi:10.37284/eajab.6.1.1815.

INTRODUCTION

The increasing climate changes further degrade the availability and quality of arable land and the production. Despite the awareness of the risks associated with the deterioration of ecosystem services and the measures enthroned as a result, the environment continues to degrade at an alarming rate (Torquebiau, 2014; Lavel et al., 2014).

Burundi is increasingly facing serious problems related to climate change coupled with high population growth. Water and soil resources are essential for the economic and social development of Burundi. Today, these resources are under severe pressure from population growth, overuse of land and growing demand for natural resources.

Burundi's soil is gradually losing its fertility following increasing degradation. Approximately, a third of cultivated soils in Burundi are acidic [Ph < 5.0] (Ntiburumusi, 1989). According to recent studies, the majority of regularly cultivated soils are also deficient in phosphorus for 85% of the cultivated land, boron (90%), sulphur (71%), zinc (62%), potassium (30%) and calcium for 68% (ISABU et al., 2013). This degradation is manifested through the reduction in productivity linked to soil degradation and infertility (Dirzo, & Raven, 2003; Mugume, 2014).

Mumirwa region represents 12% of the country's surface area with an average population density of 300 inhabitants per km², land losses are estimated at 150 tons of land per hectare (a stripping of arable soil of one cm/year). Under these conditions, all the soil in certain areas of this region could be degraded and lost within twenty years if strong measures are not taken (Gihimbare, Ndabirorere & Ruzima, 2011). The Mumirwa region is also the most threatened ecological zone. The land isexploited to the maximum with poor farming practices on fairly steep slopes and a high population density leads to extensive farm fragmentation. The losses of agricultural land due to erosion and gullying linked to unsuitable agricultural practices are enormous and the sediment loads of the rivers are very high. (Bontems & Rotillon, 2013)

Faced with such constraints, the agroecological model offers new modes of production and consumption in the service of food security and sovereignty. Mumirwa of Bubanza province is the region where the project to promote agroecological innovations was implemented by ADISCO NGO. These practices include the development of agro-ecological farms (crop association, crop rotation, agroforestry, anti-erosion ditches), biofertilizers, and biopesticides. Several authors such as Gliessman, (2006) and Villaverde et al., (2016) highlight that agroecological innovations improve the recycling of biomass and optimize the availability of nutrients and the balance of nutrient flows, ensure soil conditions favorable to plant growth (management of organic matter, soil cover,

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

improvement of soil biological activity), minimize losses of solar energy, air and water, promote the genetic diversification of species and promote favorable biological interactions. Those agricultural techniques are essential for improving yields and making agriculture more sustainable.

The study was guided by the research question: Do the agro-ecological innovations have a positive impact on agricultural production and soil fertility? The objective of study was to analyse the impact of agro-ecological practices on agricultural production and the environment specifically on soil fertility.

MATERIALS AND METHODS

Description and Choice of the Study Area

This study was conducted in the Mumirwa agroecological region, more precisely in three rural communes of the Bubanza province (Bubanza, Musigati and Rugazi). The study zone was chosen as the area of interest for the research for two main reasons: first, it is the zone where agroecological innovations was more implemented, especially by ADISCO NGO and secondly, it is among the most productive regions of crops in Burundi, especially the beans.

Data Collection and Sampling

The realization of this study covering a period from 2020 to 2022 have combined three methods: documentary exploitation, surveys, individual and collective interviews with different actors involved in agroecological innovations development.

As this study is carried out within the framework of a project, the sampling comprised 6062 households supported by ADISCO NGO and spread over 9 hills of the three rural communes of the province of Bubanza. Rea & Parker (1997) equation was used to determine the sample size.

$$n = \frac{t^2 * p(1-p) * N}{t^2 * (1-p) + (N-1) * e^2}$$

With: N: population size; n: sample size; p: expected proportion of a population response or actual proportion; t: sampling confidence interval; e: margin of sampling error.

This approach yields a meaningful sample that can represent the total population. In this study's context, the adoption rate of agroecological practices is not known in the targeted area. In this situation, the solution is to set the value of p at the level of 0.5, which maximizes the sample size. The margin of error assesses the degree of uncertainty associated with estimates made from a sample (Vaillant, 2010); thus, we made a precision of 95 chances of not making errors.

By rounding up, we obtain a sample of 341 producers.

$$n = \frac{1{,}96^2 * 0{,}5(1-0{,}5) * 6062}{1{,}96^2 * (1-0{,}5) + (6062-1) * 0{,}05^2} = 341$$

Eighteen focus group discussions were conducted with 341 producers from the 9 hills of three municipalities (Bubanza, Rugazi and Musigati) to identify agroecological practices as well as their periods of introduction or adoption. Those focus group discussions have allowed us to determine 159 producers who have had agricultural training on agro-ecological practices and 182 who have not obtained any agro-ecological practices.

Among those 159 households, the statistical description enabled us to find 69 producers who had adopted all the agro-ecological practices (development of agro-ecological farms, biofertilizers and biopesticides). We randomly chose 69 other producers among the 182 who had no training (which means that they have not adopted the agroecological practices). Questionnaires were conducted on the two samples (the first for treatment and the second for the comparison) to estimate the impact of agroecological practices on the households' production and soil fertility.

In the same framework, five partners have been interviewed such as the NGOs working with

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

producers in the experimentation and development of agroecological practices, the agricultural technicians of ADISCO NGO and the responsible of the laboratory of the Higher Agronomic Institute of Burundi (ISABU). In assessing the impact of agro-ecological practices on the soil, we retained the information provided by the ADISCO technicians who have studied the soil before and after introducing agro-ecological practices. The samples were taken at the Higher Agronomic Institute of Burundi (ISABU) laboratory.

Data Treatment and Analysis

The survey data collected via Kobo collect, have been treated with Microsoft Excel version 2013 software, STATA 17 and SPAD version 5.5 software. To analyse the impact of agro-ecological innovations on agricultural production, we used the OLS model (ordinary least squares), a regression model of a quantitative variable on a mixture of binary and quantitative variables. The model variables are Model: Y= β0 + β1formagr+ β 2Dfae+β3Biof+ β4Biop+ β5Age+ β6 Sex+ β7Edu+ β8Bov+ β9 cap+ β10 vol+ ɛi with: β0: constant, formagr: agricultural training, Dfae: development of agroecological farms, Biof: biofertilizers, Biop:

bio pesticides, Age: age, Sex: gender, Edu: level of education, Bov: cattle, cap: goats, flight: poultry, ɛi: error term.

The producers' perceptions have been used to assess the importance of agroecological practices and their impact on both production evolution and soil fertility. Futhermore, the triangulation of several data collection and analysis techniques allowed us to ensure the validity of the results.

RESULTS AND DISCUSSION

This part presents, analyses and discusses the results of the estimation of OLS model for linear regression; In addition, the perceptions of producers or other actors in innovations practices have been exploited for analysis in relation with the study objective.

Impact of Agro Ecological Practices on Bean Production

The results of the *Table 1* show that the agricultural training, the development of agro-ecological farms, bio-fertilizers, bio-pesticides, cattle, goats, rabbits positively influence bean production.

The model's coefficients are positive and significant ($p < 5\%$). For example, if cattle increase by one unit, all other things being equal, agricultural production increases by 2.21. The other variables are not significant because their probabilities are greater than 5%. The figures below illustrate the evolution of bean production from 2020 to 2022 for farmers who have adopted agroecological practices and famers who have not adopted them.

Agroecological practices were implemented in 2020; there was after an evolution in production in 2021 followed by a slightly production fell in 2022 for the practitioners which is the same tendency for the non-practitioners, but the extent of evolution is not the same. Both practitioners and non-practitioners explained that this decrease was linked to the climatic shocks that have taken place in the country that year production. The higher drop for producers who do not practice agroe-cological practices comes from their soil degradation which could cost them more for restoration. When soil is degraded, agricultural production costs increase and producer surplus will decrease (Dirzo, & Raven, 2003; Eaton & Kortum, 1996; Gomiero, 2016). During the year 2022 for example, the average bean production for the practitioners is 208,28 kg, the minimum production is 150 kg, and the maximum output is 300 kg while the average bean production for the non-practitioners is 16.71 kg with the minimum production is 100 kg and the maximum production of 250 kg.

Producers who have adopted agroecological practices explained that instead of buying chemical fertilizers, they invest in livestock to have sufficient organic manure thanks to recycling harvest residues (FAO, 2005; Van der Ploeg et al., 2019).

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

Table 1: Results of robust OLS statistical estimates

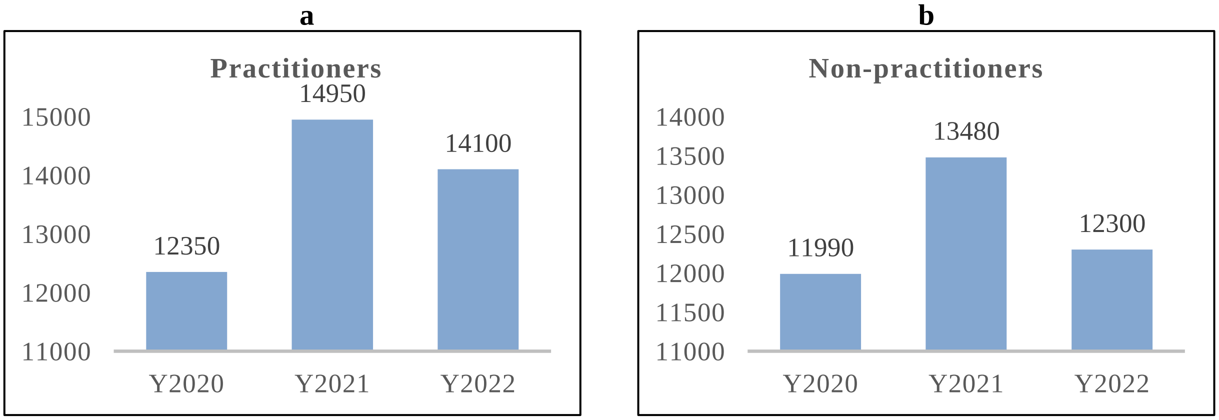
Code	Variable	Average/%	Coefficient	P>t
Formagr	agricultural training	5,2	19.9358	0.000
Dfae	development of agro-ecological farms	75%	5.363108	0.001
Biof	Biofertilizers	77%	2.098457	0.004
Biop	organic pesticides	87%	8.881552	0.000
Mirr	micro irrigation	47%	-6.44467	0.212
Sexe	Sex		-4.65488	0.144
Age	Age	43,4	-0.1670508	0.507
Edu	education		-3.723784	0.111
Taillefam	Household size	5,7	0.7030091	0.535
Bov	cattle	3,2	2.212907	0.007
Ca	goats	5,3	3.200143	0.000
Lap	rabbits	2,3	1.493219	0.003
Vol	poultry	7,2	-1.101756	0.135
Cons	constant		184.3502	0.000

Legend[1] *formagr: agricultural training, Dfae: development of agroecological farms, Biof: biofertilizers, Biop: bio pesticides, Age: age, Sex: gender, Edu: level of education, Bov: cattle, cap: goats, flight: poultry*

Source: author using STATA 17

Figure 1: Evolution of bean production for practitioners (a) and non-practitioners (a)

a b



Source: Author using Excel 2013

Impact of Agroecological Practices on the Soil Fertility

The results of the chemical analyses of the soil samples of the different agroecological practices are recorded in the next table (nine samples before planting beans and twenty-seven after) (see *Table 2*).

Before planting the bean, the carbon content is 2.04%, the nitrogen content is 0.332% with the pH of 6.83. After planting beans (*Table 3* below): With the use of organic manure (1), the pH remained almost stable (6.83 to 6.8); percent carbon is high from 2.04 to 2.51 and percent total nitrogen is high from 0.332 to 2. With chemical fertilizers (2), the pH is raised from 6.83 to 7.15; percent carbon varied from 2.04 to 2.32 and percent total nitrogen decreased from 0.332 to 0.208. With chemical fertilizers and organic matter (3), the pH decreased from 6,83 to 6.83; the carbon decreased from 2.04

[1]formagr: agricultural training, Dfae: development of agroecological farms, Biof: biofertilizers, Biop: bio pesticides, Age: age, Sex: gender, Edu: level of education, Bov: cattle, cap: goats, flight: poultry

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

to 2.03 and the nitrogen decreased from 0.332 to 0.311 .

The analysis of the data on the soil samples generally indicates that the combination of agro-ecological practices improves the chemical characteristics of the soil compared to organic manure. This could be explained by the development of agro-ecological farms and biofertilizers promoting the sedimentation of particles of organic matter from runoff water and organic manure. These results on improving chemical characteristics by combinations of agro ecologic practices align with the results found by Zougmoré et al. (2004).

Table 2: Soil study before planting beans

Sample	nº Laboratory	pH (water)	carbon (%)	nitrogen (%)
Soils of zone area study	L2289	6.83	2.04	0.332

Source: ISABU laboratory results of soil samples provided by ADISCO

Table 3: Soil study after planting beans

Sample	nº Lab	pH (water)	carbon (%)	nitrogen (%)
Lot 1 : Organic manure	M 84	6.8	2.51	2
Lot 1 : Chemical fertilizers	M 85	7.15	2.32	0.208
Lot 1 : Organic and chemical fertilizers	M 87	6.35	2.03	0.311

Source: ISABU laboratory (Lab) results of soil samples provided by ADISCO

Agroecology tries to offer a way to "make agriculture more sustainable, both socially and economically and environmentally (Anil, Kumari, & Wate, 2014; Gliessman, 2006). Van der Ploeg et al., (2019) also showed that agroecology makes it possible to manage agroecosystems in a productive and viable way by preserving natural and cultural resources.

Municipal agronomists interviewed explain that by adopting the agroforestry approach, farmers have contributed in maintaining or restoration the soil fertility favorable to improving yields. In addition, In the same way, manure of the livestock more used in the area have permitted to restore resilience and viability which can ensure high and sustainable production. ADISCO NGO has been involved in agroforestry by distribution of trees such as tithonia, Caliandra, Leucaena, Tephrosia, Artimesia. In our interview, ADISCO experts confirm that enrichment and concentration of organic matter in surface soils has improved the soil quality and water infiltration. On the environmental level, our interlocutors mention that those agro ecological practices permit to avoid water erosion and increase the biodiversity and biological activity (development of earthworms, the concentration of microfauna on the surface; saprophytes for example). They contribute to the reduction of the greenhouse effect by reducing energy expenditure, the storage of carbon in the soil (sequestration).

In relation with the perception of producers and key informants interviewed, the practices of agroforestry, crop rotation and association, anti-erosion ditches, living hedges, mulching aim to improve soil fertility (20.38%), compensate for climatic hazards (8.53%), fight against water erosion (47.87%), have a better yield (10.90%) and to promote better conservation of soil moisture (12.32%). In combination, the legume, through its leaves and branches, provides soil cover, which helps to increase soil moisture and the leaves that fall during its development fertilize the soil. The associated cereal, benefiting from more moisture and nutrients, then experiences rapid growth.

Rotation is unanimously recognized as a practice for improving soil fertility. These practices improved the availability of nitrogen usable by crops, thanks to the mechanisms of atmospheric fixation and decomposition of crop residues (LaRue & Patterson, 1981). For the producers, the leaves of

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

the trees that fall while decomposing increase the stock of organic matter. This makes it possible to have more humidity under the tree crowns (tetonia, caliandra, leucaena, tifrosia, artimesia, etc.).

Producers perceive the use of biofertilizers (burying crop residues) as a technique for improving soil fertility. Regarding the conservation of humidity and the fight against water erosion, the producers say that they have noticed that the portions of the plot where the straw is buried stay moist longer, and the straw that could not be buried serves as a physical barrier and reduces runoff (Gomiero, 2016; Maurya et al., 2020). In rural area, organic manure is of various types such as compost, household waste, dead leaves from trees, detritus from runoff water, animal waste, feed refusal, and cereal straw. Producers explain this great variability like organic manure by the advanced degradation of their land which obliges them to use everything that can be used as organic matter. For them, this loss of soil fertility is the combined action of factors such as long years of continuous cultivation without fallow due to lack of land and water erosion.

The use of pesticides is perceived as a way to protect the health of producers by 60.87% of the sample, 21.744% is for the rapid growth of plants, 2.90% say that pesticides are intended to manage soil fertility. The producers who justified that the objective is to mitigate climatic hazards and fight against erosion are 5.80% and 1.45% of the sample. Biopesticides are used to fight against harmful organisms whose active principle consists of living organisms or the products of their metabolism (Villaverde et al., 2016).

CONCLUSION

According to the study results, the agro-ecological practices have a positive impact on agricultural production and soil fertility. They restore soil viability and resilience that contribute to increased production. Although the practices are of considerable importance, the retardants in adoption are numerous. The adoption constraints may be the customs and cultures of the producers without, however, ignoring the size of the farm, which shrinks from time to time due to the number of mouths to feed for each household. Thus, it would be important to study the specific agroecological innovations in our situation of lack of sufficient cultivable land in future research.

REFERENCES

Anil, M.N.V., Kumari, K., & Wate, S.R. (2014). Loss of biodiversity and conservation strategies: an outlook of Indian scenario. *Asian Journal of Conservation Biology*, *3*(2): 105-114

Bontems, P., & Rotillon, G. (2013). *L'économie de l'environnement*. Paris : Editions La Découverte.

Dirzo, R. and Raven, P.H. (2003). Global state of biodiversity and loss. *Annual Review of Environment and Resources*, 28(1): 137-167.

Eaton J. & Kortum S. (1996). Trade in ideas Patenting and productivity in the OECD. *Journal of International Economics*, 1996, vol. 40, issue 3-4, 251-278.

FAO (2005). Land and environmental degradation and desertification in Africa: issues and options for sustainable economic development with transformation. *Monograph (Joint ECA/FAO Agriculture Division)*, 10, 118p., Rome. Retrieved October 13, 2023, from https://www.fao.org/3/x 5318e/x5318e03.htm.

Gihimbare, A., Ndabirorere, S., & Ruzima, S. (2011). *Etude sur les coûts de l'inaction contre la dégradation des sols au Burundi*. Rapport final d'étude, Bujumbura, Burundi : consulté le 13 octobre 2023 sur http://www.abctaxa.be/burundi/implementation/questions-transectorielles/ evaluation-d-impact/etude-sur-les-couts-de-l-inaction-contre-la-degradation-des-sols-au-bdi

Article DOI : https://doi.org/10.37284/eajab.7.1.1815

Gliessman, S.R. (2006). Agroecology: the ecology of sustainable food systems. *Journal of Peasant Studies*, 38(3), 587-612

Gomiero, T. (2016). Soil Degradation, Land Scarcity and Food Security: Reviewing a Complex Challenge," Sustainability. *MDPI*, *8*(3), 1-41.

Hanna, R. & Oliva, P. (2016). Implications of Climate Change for Children in Developing Countries. The future of children journal, 26(1), 115-128

ISABU (2013). Amont de l'Agriculture et de l'Elevage au Burundi. Bulletin de la recherche agronomique du Burundi, n°1. Consulté le 13 septembre 2013 sur https://isabu.bi/wp-content/uploads/2021/09/Bulletin-N%C2%B01.pdf

LaRue, T.A. and Patterson, T.G. (1981) How Much Nitrogen Do Legumes Fix? Advances in Agronomy, 34, 15-38. Retrieved October 13, 2023, from http://dx.doi.org/10.1016/S0065-2113(08)60883-4

Lavel D., Bazile D., Bertrand B., Sounigo O., Vom Brocke K., & trouche G. (2014). Biodiversité agricole et systèmes paysans de production de semences, In J.-M. Sourisseau (Eds.), *Agricultures familiales et mondes à venir* (pp. 287-302). Paris, France : AFD.

Maurya, P.K., Ali, S.A., Ahmad, A., Zhou, Q., da Silva Castro, J., Khane, E., & Ali, H. (2020). An introduction to environmental degradation: Causes, consequence and mitigation. In: Environmental Degradation: Causes and Remediation Strategies, Volume 1, Eds. Kumar, V., Singh, J. and Kumar, P., pp. 1-20, https://doi.org/10.26832/aesa-2020-edcrs-01

Mugume E. (2014). *Methods for assessing soil degradation in East Africa*: *Land Restoration Training Program*, Final report, Kasese, Uganda: United Nations University. Retrieved October 13, 2023, from http://www. unulrt.is/ static/fellows /document/ Mugume

Ntiburumusi, F. (1989). Arrière-effet du chaulage sur la productivité d'un kaolisol humifère dans la région naturelle du Mugamba (Burundi). *Publication ISABU*, n° 135.

Rea, L. M., & Parker, R. A. (1997). *Designing and Conducting Survey Research: A Comprehensive Guide*. San Francisco, CA: Josey-Bass Publishers.

Torquebiau, E. (2024). *Changement climatique et agricultures du monde*. Paris: Éditions Quae.

Vaillant, J. (2010). "The methodological challenge of monitoring living conditions. Insights from a tracking experience in Madagascar," *Working Papers* DT/2010/13, DIAL.

Van der Ploeg, J. D., Barjolle, D., Bruil, J., Brunori, G., Madureira, L.M., Dessein, J., Drąg, Z., Fink-Kessler, A., Gasselin, P., Molina, M.G, Gorlach,K., Jürgens, K., Kinsella, J., Kirwan, J., Knickel, K., Lucas, V., Marsden, T., Maye, D., Migliorini, P., Milone, P., Noe, E., Nowak, P., Parrott, N., Peeters, A., Rossi, A., Schermer, M., Ventura, F., Visser, M., & Wezel, A. (2019). The economic potential of agroecology: Empirical evidence from Europe, *Journal of Rural Studies*, *71*(1), 46-61.

Villaverde, J.F., Guerrón-Quintana, P., Rubio-Ramírez, J. (2015b). Estimating dynamic equilibrium models with stochastic volatility. Journal of Econo-metrics 185, 216–229.

Zougmoré R., Ouattara K., Mando A., & Ouattara B. (2004). Rôle des nutriments dans le succès des techniques de conservation des eaux et des sols au Burkina Faso. *Journal de Science et changements planétaires/Sécheresse*, *15*(1), 4-8.