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THE ROLE OF MIXED CROPPING TO CLIMATE CHANGE IN SOFI DISTRICT, HARARI REGIONAL STATE, ETHIOPIA

HANAA THARWAT MOHAMED IBRAHIM – MODIBA MAIMELA MAXWELL – IGOR DEKEMATI – BARBARA SIMON – MUKTAR MOHAMMED – LISANWORK NEGATU

Abstract

The negative impact of climate change has been striking the agricultural sector in Africa. For countries like Ethiopia, whose livelihood occupation of the nation is mainly based on subsistence agriculture that highly rely on rainfall, making an adjustment to adapt to the changing situation is very crucial. Therefore, designing contextual specific adaptation strategies are essential to moderate the negative effect of climate change. The aim of the study was to identify the agricultural practices and conserve natural resources. Three stages sampling procedure was followed in selecting the study district, villages and representative respondents. Accordingly, one kebele and 60 household heads were selected using purposive sampling and systematic random sampling, respectively. In addition to the soil data and secondary data, structure interview schedule was developed, pre-tested and used for collecting quantitative data. The soil analysis result showed that organic agriculture contributed for the improvement of soil chemical property that is the mixed cropping farming practice was significantly different in soil pH, nitrogen, organic matter, organic carbon and available phosphorous than in mono cropping farming system. The descriptive result showed that all the farmers (100%) of the sample respondent participated in land preparation and 98.3% of them participated in manure application and also 98.3% of the sample respondents in participated weeding practices. 98.3% of the sample respondents were participated in harvesting activities. 93.3% of the sample respondents were participated in the fertilizer application activities. 68.3% of the sample respondents were participated in irrigation activities. 13.3% sample respondents were participated in seed treatment activates. To adopt organic agriculture practices whereby financial institutions and other agricultural funders should extend credit or support to agricultural activities with farming practices and technologies that promote organic agriculture. This study has shown that organic agriculture can contribute to better soil health and therefore better crop yields thereby strengthening the adaptation efforts of smallholder farmers. It is therefore recommended that smallholder farmers in Sofi district practice organic agriculture farming practices for adaptation efforts.

Keywords: *crops, mixed farming, mono-farming, resilience, smallholder farmers, Ethiopia*

A VEGYES GAZDÁLKODÁSI GYAKORLAT SZEREPE AZ ÉGHAJLATVÁLTOZÁS MÉRSÉKLÉSÉBEN ETIÓPIÁBAN (SOFI DISTRICT, HARARI REGIONAL STATE)

Összefoglaló

Az éghajlatváltozás negatív hatásai intenzíven sújtják az afrikai mezőgazdasági ágazatot. Az olyan országok számára, mint Etiópia, amelyek megélhetése elsősorban a csapadékra támaszkodó önellátó mezőgazdaságon alapul, nagyon fontos, hogy alkalmazkodjanak a változó helyzethez. Ezért az éghajlatváltozás negatív hatásainak mérsékléséhez elengedhetetlen a kontextus-specifikus alkalmazkodási stratégiák kidolgozása. A tanulmány célja az volt, hogy azonosítsa azokat a mezőgazdasági gyakorlatokat, amelyek maximalizálják a termelést és kímélik a természeti erőforrásokat.

A vizsgálati körzet, a falvak és a reprezentatív válaszadók kiválasztása során háromlépcsős mintavételi eljárást követtek. Ennek megfelelően egy közigazgatási egységet (kebele) és 60 háztartásfőt választottunk ki célzott mintavétellel, illetve szisztematikus véletlenszerű mintavétellel. A talajadatokon és a másodlagos adatokon kívül szerkezetinterjú ütemtervet dolgoztunk ki, előzetesen teszteltük és felhasználtuk a kvantitatív adatok gyűjtésére. A talajelemzés eredménye azt mutatta, hogy az ökológiai mezőgazdaság hozzájárul a talaj kémiai tulajdonságainak javításához, vagyis a vegyes gazdálkodási gyakorlat a talaj pH-értéke, nitrogénje, szervesanyag-tartalma, szerves szén- és elérhető foszfortartalma szignifikánsan eltér a monokultúrás gazdálkodási rendszertől.

A leíró eredmény azt mutatja, hogy a minta válaszadójának valamennyi gazdálkodója (100%) részt vett talaj-előkészítésben és 98,3%-uk trágyakijuttatásban, valamint a minta válaszadóinak 98,3%-a vett részt gyomirtásban. A mintában szereplő válaszadók 98,3%-a vett részt betakarítási tevékenységben; 93,3%-uk a műtrágya kijuttatási tevékenységben; 68,3%-uk pedig öntözési tevékenységben, valamint 13,3%-uk vetőmagkezelési aktivitásban vett részt. Ökológiai mezőgazdasági gyakorlatok elfogadása, amelyek révén a pénzügyi intézményeknek és más mezőgazdasági finanszírozóknak hitelt vagy támogatást kell nyújtaniuk a mezőgazdasági tevékenységekhez olyan gazdálkodási gyakorlatokkal és technológiákkal, amelyek elősegítik az ökológiai gazdálkodást. Ez a tanulmány kimutatta, hogy az ökológiai mezőgazdaság hozzájárulhat a talaj jobb egészségi állapotához és ezáltal a jobb terméshozamhoz, ezáltal erősítheti a kistermelők alkalmazkodási erőfeszítéseit. Ezért javasoljuk, hogy a Sofi kerületben (Sofi District) élő kistermelők alkalmazzanak ökológiai mezőgazdasági gazdálkodási gyakorlatokat a klímaváltozáshoz való alkalmazkodáshoz.

Kulcsszavak: *vegyes gazdálkodási gyakorlat, Etiópia, ökológiai gazdálkodás, kistermelők*

Introduction

Agriculture is considered a key sector in the transformation of societies to greener economies. Global crop production has more than doubled over the last 40 years and the world now produces enough food to feed six billion people, although the distribution of this food is uneven. Numerous efforts are created to estimate the share of the world's food created by smallholders (FAO, 2014; HERRERO et al., 2017; RICCIARDI et al., 2018) and by family farms (FAO, 2014; GRAEUB et al., 2016). In some instances, the estimates made by Food and Agriculture Organization of the United Nations (2014) that family farms turn out quite 80% of food within the world have been erroneously taken like smallholders produce more than 80% of the world's food (RICCIARDI et al., 2018).

Agriculture in Ethiopia is the foundation of the country's economy, accounting for half of gross domestic product (GDP), 83.9% of exports, and 80% of total employment (MAC DONALD and SIMON, 2010). A potential exists for self-sufficiency in grains and for export development in livestock, grains, vegetables, and fruits as many as 4.6 million people need food assistance annually (MATOUS and TODO, 2013). The negative impact of climate change has been striking the agricultural sector in Africa. For countries like Ethiopia, whose livelihood occupation of the nation is mainly based on subsistence agriculture that highly rely on rainfall, making an adjustment to adapt to the changing situation is crucial.

Organic agriculture practice has been fronted as a good alternative for smallholder farmers to adapt to climate change. Organic agriculture represents a variety of integrated farming practices that emphasize the use of naturally and sustainably produced soil nutrients and cultivation of diversified crops and livestock husbandry in a manner that enhances overall farm productivity in balance with local, regional and global environmental resources (BYERLEE and JANVRY, 2007). In several parts of Ethiopia, smallholder farmers have been using organic practices with others having adopted in the recent past, however there is limited information at farm level on the contribution of organic agriculture to climate change adaptation. Therefore, this study identified the organic agriculture practices that enhance agriculture production in the Sofi District.

Organic agriculture refers to the increasing use of farming practices and technologies that maintain and increase farm productivity and profitability while ensuring the provision of food on a sustainable basis, reduce negative externalities and gradually lead to positive ones and rebuild ecological resources (soil, water, air and biodiversity) by reducing pollution and using resources more efficiently (UNEP, 2011). Organic agriculture has a role to play in climate change adaptation, including avoided damage, and many farming practices contribute to both processes. It provides management practices that can help farmers adapt to climate change through strengthening agro-ecosystems, diversifying crop and livestock production, and building farmers’ knowledge base to best prevent and confront changes in climate (FAO, 2004).

Farming practices and technologies that are instrumental in organic agriculture include: restoring and enhancing soil fertility through the increased use of naturally and sustainably produced nutrient inputs, diversified crop rotations, livestock and crop integration, reducing soil erosion and improving the efficiency of water use by applying minimum tillage and cover crop cultivation techniques, reducing chemical pesticide and herbicide use by implementing integrated biological pest and weed management practices and reducing food spoilage and loss by expanding the use of post-harvest storage and processing facilities.

This study is important for the regional government and other rural development actors which aim at formulating and implementing strategies for organic agriculture. The aim of the study was to identify the agricultural practices and conserve the natural resources.

Materials and methods

Site description

The study was conducted in Sofi District, Harare Regional State (Figure 1). The Harari Regional State (HRS) is located in one of the upstream micro-watersheds of the Wabi Shebelle River Basin (HPRS, 2011). In Harari region the mean annual temperature varies from 10°C in high lands and 26°C in low lands. The last four years record of rainfall shows that it ranges from 700mm in the south east and over 900mm in the western part of the region. In Sofi the rainfall ranges from 850mm to 870mm bi-modal with peaks in April and August 60 - 90days (CSA, 2013).

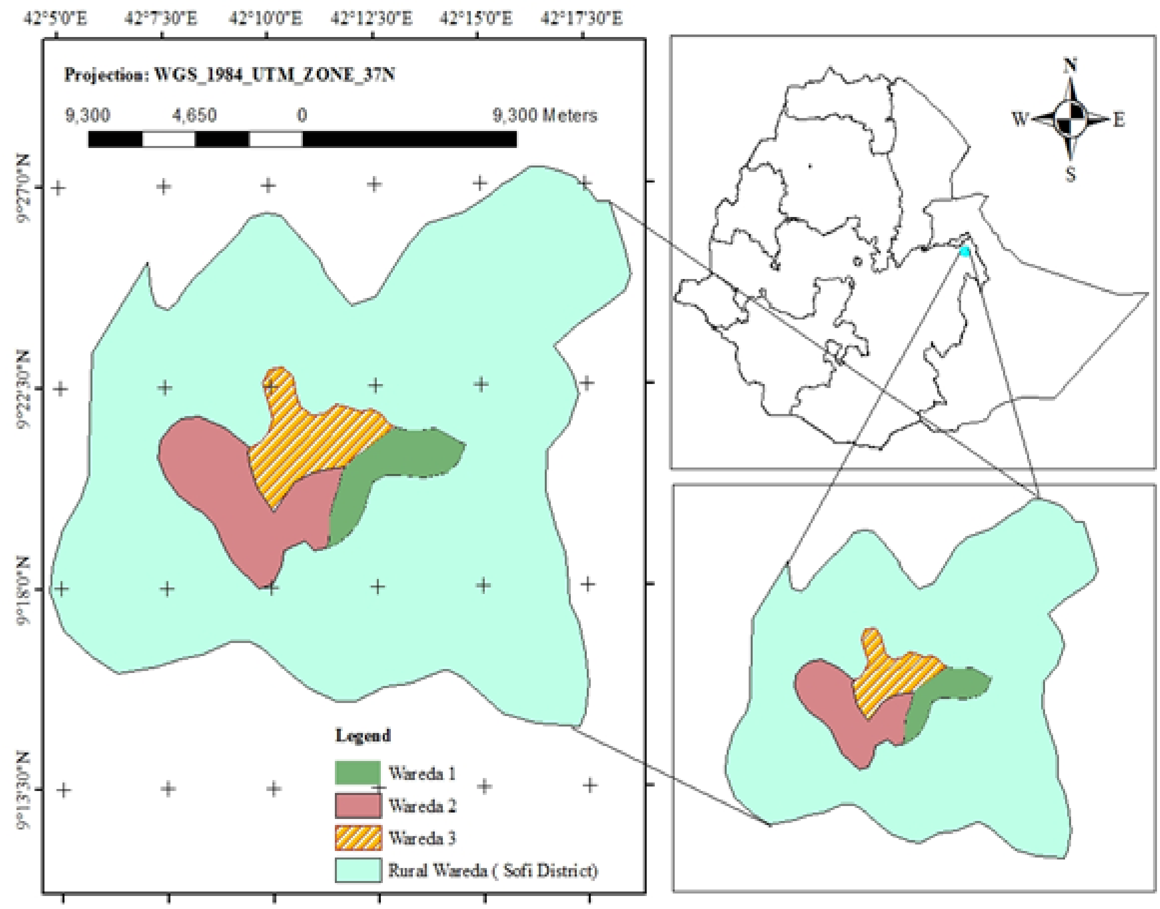

Figure 1. Sofi District, Harare Regional State

Types and source of data

In this study, both qualitative and quantitative data from primary and secondary sources were used. The primary data were collected from sampled households, extension agents, regional agricultural offices and Secondary data were collected from records of the district and regional agricultural offices and related literature prepared by government and nongovernmental organization.

Soil Sampling

Soil samples were taken with a hand trowel for the determination of chemical, physical and biological properties of soils under nine farms operating on mono cropping and mixed cropping systems (Table 1). Two (2) soil samples were collected from each of the nine sampling plots on a demarcated site of 20 × 20m quadrat. In all, a total of eighteen (18) soil samples were collected at 0-30cm depth to represent the average plough layer, to achieve the quality of the soil physical, chemical and biological properties that suitable for organic agriculture.

Table 1. Soil chemical, physical and biological analysis: methods and instruments used

S. No	Parameters	Methods employed	Instrument/apparatus used
1	Texture	Hydrometer method	Bouyoucos hydrometer
2	Bulk density	Method for disturbed soils- the weight of oven dried soil filled in Pycnometer by gently tapping divided by its volume.	Pycnometer
3	pH	1:2 Soil water suspension (JACKSON, 1973)	pH meter
4	Organic Carbon	Rapid titration method (WALKLEY and BLACK, 1934)	Titration
5	Total Nitrogen	Alkaline potassium permanganate method (SUBBIAH and ASIJA, 1956)	Kjeldhal distillation unit
6	Available Phosphorus	OLSEN et al., 1954	Spectronic 20-D^{+}
7	Available Potassium	Neutral 1N ammonium acetate solution method (MERWIN and PEACH, 1951)	Flame Photometer
8	Exchangeable Calcium and Magnesium	Neutral 1N ammonium acetate solution method (MERWIN and PEACH, 1951)	Atomic absorption spectrophotometer (Elements AS AAS4141)
9	Microbial biomass	Fluorescein diacetate test (2012)	Spectrofluorometer

Crop diversification

The crop diversity within the farmers land under the study area between the sample quadrates were computed by using Shannon’s diversity index (KREBS 1999; MAGURRAN 2004; WITTENBERG et al., 2004).

$$H=-\sum[(pi)\times\ln(pi)]$$

where H = Shannon’s diversity index, pi = the relative importance value of the ith species, and s = the total number of species in the sample quadrat. The percentage cover of the species was computed from Shannon’s diversity index as:

$$E = H / \ln(k)$$

where k is the number of species. E= Evenness gives you a value between 0 and 1

Results and discussion

Farm level activities in Sofi district

Farmers engaged in a range of farm level activities including weeding, manure application irrigation among others (Table 2). The participation level in most of these activities was above 98 percent (Table 2). The distribution of farmers by their crop production adaptation practice revealed that all (100%) the sample respondent participated in land preparation and 98.3% of them participated in manure application and also 98.3% of the sample respondents participated in weeding practices. Moreover 98.3% of the sample respondents participated in harvesting activities. 93.3% of the sample respondents were participated in the fertilizer application activities. 68.3% of the sample respondents were participated in irrigation activities. 13.3% sample respondents were participated in seed treatment activates. This indicated these activities as key farming engagements that define farm level time allocation among the smallholder farmers in Sofi. Further, these activities are critical in ensuring the stability of agricultural production. For example, composting and manure application have been known to enhance nutrient cycling essential for high agricultural productivity (LAL, 2004).

Table 2. Farmer farm practices

	Yes		No	
	Frequency	**%**	**Frequency**	**%**
Land preparation	60	100	0	0
Compost/Manure application	59	98.3	1	1.7
Weeding	59	98.3	1	1.7
Irrigation	41	68.3	19	31.7
Mixed cropping	50	88.3	1	1.7
Fertilizer application	56	93.3	4	6.7

Influence of organic and non-organic farming practices on soil properties

The mean values of soil physic-chemical properties are highest in mixed cropping system than mono cropping system.

Table 3. Soil physical properties

	Mean	**Std. Error**	**P-value**	**t-value**
Soil texture				
Clay (%)				
Mono-cropping	11.0000	1.500	0.735	0.352
Mixed cropping	10.3571	0.870		
Sand (%)				
Mono-cropping	8.0000	1.500	0.399	-0.898
Mixed cropping	9.9286	1.043		
Silt (%)				
Mono-cropping	8.0000	1.500	0.399	-0.898
Mixed cropping	9.9286	1.043		

Bulk density (gm/cm^3)				
Mono-cropping	1.300	0.017	0.010	-3.381
Mixed cropping	1.4440	0.029		

The result on Table 3 shows that, the higher sand particles observed in mono cropping farm use type may be presumably due to erosion caused by the long period of intensive cultivation while the lower proportion of silt particles under mixed cropping suggested that cultivation of crops especially under continuous mono cropping reduces silt particles in soil. This may also be attributed to erosion, which removes finer particles of soil due less vegetative cover that could reduce the impact of raindrops on soil in the cultivated plots. It is necessary to increase the ground cover to reduce soil loss and to incorporate organic manure to aid aggregation and stability of the soil. The possible reason for the increase of bulk density in soil of mixed cropping is due to increase in the period of cultivation. This was in agreement with works of SINTAYEHU (2006) and LEMENIH *et al*. (2005), who postulated that the significant difference is due to differences in the land management and land use history but contradict. Bulk density was higher in the mixed cropping however the result corresponds with the observation of (DALAL 1982) that bulk density increases with increase in the period of cultivation. This otherwise shows that as cultivation causes decline in the organic matter, the bulk density increase.

Table 4. Soil chemical and biological properties

	Mean	**Std. Error**	**P-value**	**t-value**
Nitrogen %				
Mono-cropping	9.00	1.220	0.049	2.335
Mixed cropping	11.70	1.156		
Phosphorous (ppm)				
Mono-cropping	17.82	1.060	0.005	4.054
Mixed cropping	18.20	1.067		
Potassium (mg/kg soil)				
Mono-cropping	371.18	32.43499	0.778	0.24
Mixed cropping	337.76	152.84195		
OC%				
Mono-cropping	0.3347	0.25156	0.024	2.876
Mixed cropping	1.5900	0.35668		
pH				
Mono-cropping	7.80	0.140	0.123	-1.752
Mixed cropping	8.10	0.22		
Exchangeable Ca and Mg (mg/kg soil)				
Mono-cropping	0.0008	0.00007	0.519	-0.679
Mixed cropping	0.0031	0.00459		

Microbial biomass				
Mono-cropping	17.83	3.94	0.064	-2.200
Mixed cropping	25.66	1.676		

The higher value in mixed cropping farmlands can be explained in terms of the types of crops they grow that fixed nitrogen and rapid humification. The lower mean values in mono may be attributed to inadequate application of nitrogen based chemical fertilizers, increasing immobilization by plants as well as leaching and volatization which is common to most mineral soils (JONES and WELD 1975; BRADY and WEIL, 2002). The lower concentration of total nitrogen in mono cropping reflected the organic matter diminution as organic matter has a direct influence on it (AWETO, 1981). This could be attributed to the leaching of nitrogen in its soluble form as it (leaching) is accelerated by clearing of vegetation and higher percentage of sand content. KOWAL and KASSAM (1978) stressed that the nitrogen status of the soil is closely associated with the soil organic matter as it (organic matter) is the major source of soil nutrients. This nutrient decline is also due to nutrient removal while harvesting crops because the crops store large quantities of nitrogen (COOKE, 1982).

Available phosphorous (P) which increases plant resistance to disease higher in mixed cropping than mono cropping farming system. The mean was 17.825mg/kg soil and 18.205mg/kg soil for mono cropping and mixed cropping farmlands respectively. The phosphorous content on mixed cropping is basically high. This also goes with high organic matter content obtained on mixed cropping (ADAMU and DAWAKI 2008). This finding was in agreement with MOGES and HOLDEN (2008) as well as WOLDE and VELDKAMP (2005) who found higher mean value of available Phosphorous from mixed cropping compared to mono cropping. The higher phosphorous content in mixed cropping could be associated with higher soil organic matter. The application of good organic manure is important for the maintenance of available phosphate to the crops.

Table 4 shows that, there is no significant difference between the two-cropping system on the available potassium. Potassium equally decreases from a mean of 371.18cmol/kg to 337.76 cmol/kg in mono cropping and mixed cropping farmlands respectively. This reduction delays plants growth and hence variation in crop yields is bound to occur between the cropping systems. (CHAPMAN, 1965). The low amount of K in the mixed cropped soils may have also contributed to the high Ca and Mg values because of its better competitive ability for exchange sites, although their values are not however extremely bad (FOLORONSHO,1998).

Organic carbon content of the mixed cropping farmlands was higher than the mono cropping farmlands. The mean of the two-cropping system was 0.33% and 0.59% in mono cropping and mixed cropping farmlands respectively. The fairly high level of Organic carbon observed in the mixed cropping site can be due to the humus formed by fallen leaf and dead plant decaying on the surface. Differences between the two cropping systems may reflect the differences in vegetation cover, turnover of organic carbon and the degree and frequency of soil disturbance. The relatively low organic carbon in mono cropping system may be attributed to their lost through extensive cultivation and mixed cropping.

Soil organic carbon was increased by N inputs from both fertilizer and by retention of residues and by N fixation in case of the legume planted (SHAH et al., 2003). These results concurred with those reported by (SUREKHA *et al*., 2003; SHAH *et al*., 2007). The analysis of organic carbon is related to WOODRUFF (1949) view that says whenever virgin soils are brought under cultivation and cropping, organic carbon content generally declines because the number of organic materials returned to the soil decreases sharply. The lower organic matter content of mono cropping compared to mixed cropping was therefore due to site clearance before cultivation which would have disrupted the rate of organic matter decomposition (NYE and GREENLAND et al., 1985), and this would have given chance for erosion and leaching to degrade the soil. Meanwhile the soil pH analysis is similar to the findings of (AWETO *et al*., 1992) in south western Nigeria.

There was no significant variation between mono cropping and mixed cropping as soil erosion is prevalent from these areas. The highest pH value from mixed cropping and mono cropping could be due to high CEC and exchangeable bases. This finding was in line with the findings of MOGES and HOLDEN (2008) who found no significant difference in pH. This result was in agreement with the finding of ASADI *et al*. (2010) who found a non-significant difference in soil pH between soils on mono cropping farm land and mixed cropping farm land of semiarid region of Iran.

Table 4 shows that, there is no significant difference between the two-cropping system on the content of exchangeable calcium and magnesium. The mean of exchangeable calcium and magnesium content for mono cropping was 0.0008 cmol/kg and 0.0031 cmol/kg for mixed cropping respectively.

Microbial biomass of the mixed cropping farmlands was higher than the mono cropping farmlands. The mean of the two-cropping system was 17.83 and 25.66 in mono cropping and mixed cropping farmlands respectively. The fairly high level of Microbial biomass observed in the mixed cropping site can be due to soil was wet or have enough organic carbon. Differences between the two cropping systems may reflect the differences in vegetation cover, turnover of organic carbon and the degree and frequency of soil disturbance. The relatively low microbial biomass in mono cropping system may be attributed to their lost through extensive cultivation and rainfall. SHAH *et al*. (2003) reported that soil organic C was increased by N inputs, from both fertilizer and by retention of residues and by N fixation in case of the legume planted.

Crop diversification

Table 5. Species diversity index calculation

No	Species Name	Found%	P_i	lnP_i	$P_i ln[P_i]$	Value
1	Tobacco	2.16	0.021	-3.86	0.08	0.38
2	Caster bean	0.24	0.002	-6.21	0.01	0.35
3	Cordial	0.43	0.004	-5.52	0.02	0.36
4	Sweet potatos	13.5	0.135	-2.00	0.27	0.46
5	Sorghum	46	0.460	-0.78	0.35	0.50
6	Chat	4.23	0.042	-3.17	0.13	0.40
7	Mango	0.37	0.003	-5.81	0.01	0.35
8	Wild casterard apple	0.12	0.001	-6.91	0.0006	0.35
9	Peanut	0.67	0.006	-5.12	0.03	0.36
10	Groundnut	7.72	0.07	-2.6	0.182	0.42
11	Guava	0.18	0.001	-6.91	0.0006	0.35
12	Cabbage	0.37	0.003	-5.81	0.01	0.035
13	Maize	14.6	0.146	-1.92	0.28	0.046
14	Coffee	6.4	0.064	-2.7	0.17	0.41
15	Tomato	0.86	0.008	-4.82	0.03	0.36
16	Lemon	0.61	0.006	-5.12	0.03	0.36
17	Sour sop	0.24	0.002	-6.21	0.01	0.35

A total of 17 crop species were observed (Table 5). The result of species diversity showed that crops (Sorghum, Sweet potatoes, Groundnut, Coffee and Chat) have a high abundance. This high diversity of crop species in the organic farms (nine farms) confirms the fact that organic agriculture provides a crop diversification range that acts as insurance to farmers in the event of an extreme climate event such as drought and/or flood. Crop diversification is encouraged under climate change adaptation particularly where communities are implementing Ecosystems Based Adaptation (EbA) techniques (SMIT and SKINNER, 2002; BRADSHAW *et al*., 2004), for which organic agriculture is one of them.

Conclusion

This study has shown that there are beneficial effects of mixed cropping to soil properties particularly improving soil quality. This potentially could improve agricultural productivity. Further, the study has shown that farmers in Sofia district plant multiple crop species thereby increasing crop diversity in the area, this is important for adapting to climate change. It is recommended that, the level of organization of these smallholder farmers need to be enhanced so as to maximize on the benefits accruing from organic agriculture in the area.

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References

ADAMU, G. K. – DAWAKI, M. U. (2008): NPK level in Multiple Crop Land in a Smallholder Farm Land in Kano Closed Settled Zone. Biological and Environmental Sciences Journal for the Tropics, Bayero University Kano, 5, 88– 97. DOI: https://doi.org/10.4314%2Fejhd.v21i3.10051

ASADI, RAEISVANDI – RABIEI, B. – GHARDIRI, H. (2010): Effect of land use and topography on soil properties and agronomic productivity on calcareous soils of a semi-arid region, Iran. Land degradation and Development. DOI: https://doi.org/10.1002/ldr.1081.

AWETO, O.A. – OBE, O. – AYANNIYI, O.O. (1992): Effects of Shifting Cultivation and Continuous Cultivation of Cassava (*Manihot esculenta*) intercropped with maize (*Zea mays*) on a Forest Alfisol in South Western Nigeria. Journal of Agricultural science Cambridge, 118: 195–198. DOI: https://doi.org/10.1017/s0021859600068787

AWETO, O.A. (1981b): Total nitrogen status of soils under bush fallow in the forest zone of South Western Nigeria. J. Soil Science, 32: 639–642. DOI: https://doi.org/10.1086/309626

BRADSHAW, B., DOLAN, H. and SMIT, B., (2004): Farm-level adaptation to climatic variability and change: crop diversification in the Canadian prairies. Climatic Change, 67(1), 119–141. DOI: https://doi.org/10.1007/s10584-004-0710-z

BRADY, N. C. – WEIL, R. R. (2002): The Nature and Properties of Soils 13th edition. New Jersey: Prentice Hall. DOI: https://doi.org/10.6028/nist.ir.6876

BURKE, I.C. – YONKER, C.M. – PARTON, W.J. – COLE, C.V. – SCHIMEL, D.S. – FLACH, K. (1989): Texture, climate, and cultivation effects on soil organic matter content in US grassland soils. Soil science society of America journal, 53(3), 800–805. DOI: https://doi.org/10.2136/sssaj1989.03615995005300030029x

BYERLEE, D. – JANVRY, A. (2007): World Development Report 2008: Agriculture for Development. World Bank. Washington D.C. https://doi.org/10.1596/1020-797x-10_3_2

CHAPMAN, H. D. (1965): "Cation Exchange." In Black, C.A. eds. Methods of Soil Analysis American Society of Agronomy Monograph, 9(2), 891–90. DOI: https://doi.org/10.2172/4559586

COOKE, G.W. (1982): Fertilizing for Maximum Yield. 3rd Edn., Granada Publishing Ltd., London. DOI: https://doi.org/10.2514/6.1982-1315

DALAL, R.C., (1982): Organic matter content in relation to the period of cultivation and crop yields in some subtropical soils. 12th International Congress. Soil Science., 6: 59. DOI: https://doi.org/10.1016/0044-8486(82)90035-7

FAO. (2014). The State of Food and Agriculture (2014): Innovation in family farming. DOI: https://doi.org/10.1787/c36273fb-is

FAO. (2001): The Role of Agriculture in the Development of LDCs and their Integration into the World Economy. Paper Prepared for the Third United Nations Conference on the Least Developed Countries. Rome, Food and Agriculture Organization of the United Nations. DOI: https://doi.org/10.1787/agr_outlook-2001-en

FAO. (2005): Impact of Climate Change, Pests and Diseases on Food Security and Poverty Reduction. Special event background document for the 31st Session of the Committee on World Food Security. Rome. 23-26 May 2005. DOI: https://doi.org/10.1787/agr_outlook-2005-sum-ar

FOLORONSHO, E. (1998): Evaluation of soil fertility status Under Irrigation in Jakara River Valley: A case study of Air-Port Road-Katsina Road, Kano Metropolis; Post Graduate Diploma in Land Resources Thesis; Geography department, Bayero University, Kano. DOI: https://doi.org/10.15385/yb.miracle.1998

GRAEUB, B. E. – CHAPPELL, M. J. – WITTMAN, H. – LEDERMANN, S. – KERR, R. B. – GEMMILL-HERREN, B. (2016): The state of family farms in the world. World Development, 87, 1–15. DOI: https://doi.org/10.1016/j.worlddev.2015.05.012

HERRERO, M. – THORNTON, P. K. – POWER, B. – BOGARD, J. R. – REMANS, R. – FRITZ, S. – HAVLÍK, Petr (2017): Farming and the geography of nutrient production for human use: A transdisciplinary analysis. The Lancet Planetary Health, 1(1), e33–e42. DOI: https://doi.org/10.1016/S2542-5196(17)30007-4

HPRS (2011): Harari People Regional State, Programme of Plan on Adaption to Climate Change Technical and Financial Support: Environmental Protection Authority of the Federal Democratic Republic of Ethiopia.

IPCC. (2001): IPCC third assessment report climate change. 2001. impacts, adaptation and vulnerability. Published for the Intergovernmental Panel on Climate Change by UNEP/GRID Arendal, 1032pp. Retrieved from http://www.ipcc.ch/. DOI: https://doi.org/10.1109/ipcc.2001.971597

JONES, M. J. – WILD, A. (1975): Soils of the West African Savanna: The Maintenance and Improvement of their Fertility. Haependen Commonwealth Agricultural Bureau.Kwara State of Nigeria. Kwara State Diary, Government Press Ilorin .1993. DOI: https://doi.org/10.2307/25303270

KOWAL, J.M. – A.H. KASSAM (1978): Agricultural Ecology of Savanna. A Study of West Africa, Clarendon Press, Oxford, UK. DOI: https://doi.org/10.1002/macp.1978.021790314

KREBS, C.J. (1999): Ecological methodology. Benjamia /seris in the life science. Cummings, California. Kwara State of Nigeria. Kwara State Diary, Government Press Ilorin 1993. DOI: https://doi.org/10.1515/9783110802832

LAL, R. (2004): Soil carbon sequestration to mitigate climate change. Geoderma, 123(1), pp.1–22. https://doi.org/10.1016/b0-12-176480-x/00539-8

LEMENIH, M. – KARLTUN, E. – OLSSON, M. (2005): Assessing soil chemical and physical property responses to deforestation and subsequent cultivation in small holders farming system in Ethiopia. Agriculture, Ecosystems and Environment. P. 105: 1–2. https://doi.org/10.1016/j.agee.2005.02.015

MATOUS, P.Y. TODO. (2013): Agricultural Intensification and Ecosystem Properties. Journal of Science. p. 277: 504–509. DOI: https://doi.org/10.1016/j.jtrangeo.2013.04.001

MAC DONALD, M. – SIMON, J. (2010): Climate, Food Security and Growth: Ethiopia's Complex Relationship with Livestock. Brighter Green. DOI: https://doi.org/10.2172/971515

MOGES, A. – HOLDEN, N. M. (2008): Soil fertility in relation to slope position and agricultural land use: A case study of Umbulo catchment in southern Ethiopia. Environmental Management, 42, 753–763. DOI: https://doi.org/10.1007/s00267-008-9157-8

NYE, P.H. – D.J. GREENLAND, 1998. The soil under shifting cultivation. Plant Soil, 21: 101–112.

RICCIARDI, V. – RAMAKUTTY, N. – MEHRABI, Z. – JARVIS, L. – CHOOKOLINGO, B. (2018): How much of the world’s food do smallholders produce? Global Food Security, 17, 64–72. DOI: https://doi.org/10.1016/j.gfs.2018.05.002.

SHAH – LYONS – HUGHES. (2003): Determinants of farmers’ willingness to participate in soil conservation practices in the highlands of Bale: The case of Dinsho farming system area. DOI: https://doi.org/10.1136/bmj.327.7421.993-c

SHAH, BRAWN – COOKE, J. (2007): Regulating Meaning, Appropriating Nature: The Codification of California Organic Agriculture, Antipode, 30, 2: 135–154. https://doi.org/10.1126/science.318.5854.1221a

SINTAYEHU, M. (2006): Land Use Dynamics and its Impact on Selected Physicochemical Properties of Soils in YabelloWoreda of Borana Lowlands, Southern Ethiopia [M.S. thesis], Haromaya University, Haromaya, Ethiopia.

SMIT, B. – SKINNER, M.W. (2002): Adaptation options in agriculture to climate change: a typology. Mitigation and adaptation strategies for global change, 7(1), 85–114. DOI: https://doi.org/10.1023/a:1015862228270

UNEP. (2011): Towards a Green Economy Agriculture. advance copy online release. The World 2010 World Development Report. Development and Climate Change. UNEP: http://www.unep.org/greeneconomy/SuccessStories/Organicagric agriculture in Uganda/tabid/29866/. https://doi.org/10.29171/azu_acku_pamphlet_gb1359_a3_e695_2011

WOLDE, M., – VELDKAMP, E. (2005): Impacts of landuse changes on soil nutrients and erosion in Tigray, Ethiopia, Conference on International Agricultural Research for Development, Deutscher Tropentag 2005, Stuttgart-Hohenheim, October 11–13, 2005.

WOODRUFF, C.M. (1949): Estimating the nitrogen delivery of soil from the organic matter determination as reflected by sanborn field. Soil Sci., 14: 208. DOI: https://doi.org/10.1093/jee/42.2.249

Authors

Hanaa Tharwat Mohamed Ibrahim
PhD student
Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Department of Soil Science, H-2100 Gödöllő, Páter K. u. 1. Hungary

Modiba Maimela Maxwell
PhD student
Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Department of Soil Science, H-2100 Gödöllő, Páter K. u. 1. Hungary

Igor Dekemati, PhD
Hungarian University of Agriculture and Life Sciences, Institute of Crop Production Sciences, H-2100 Gödöllő, Páter K. u. 1. Hungary

Barbara Simon, PhD
corresponding author
associate professor
Hungarian University of Agriculture and Life Sciences, Institute of Environmental Sciences, Department of Soil Science, H-2100 Gödöllő, Páter K. u. 1. Hungary
simon.barbara@uni-mate.hu

Muktar Mohammed, PhD
associate professor
Haramaya University, College of Agriculture and Environmental Sciences, Ethiopia

Lisanwork Negatu, Phd
associate professor
Haramaya University, College of Agriculture and Environmental Sciences, Ethiopia