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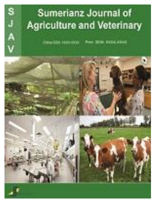

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The Use of Small Grains for Food Security and Climate Compliant In Dry Regions of Zimbabwe: A Review

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Abstract

Climate change has brought issues of total crop failure in dry regions in Zimbabwe as evidenced by total crop failure in 2010, 2015 and 2017 in some parts of Chivi which is one of the driest area in Zimbabwe. The paper highlights the use of small grains for food security and climate compliant in dry regions of Zimbabwe. This brings in an idea of growing small grain by farmers as means of improving food production in dry areas such as Chivi, Mwenezi and Chiredzi districts. Cereal production growth in Sub-Saharan Africa is expected to decline by a net 3.2 percent in 2050 as a result of climate change. To mitigate this risk, there is need to improve productivity of small grains as climate compliant crops which can ameliorate poverty in Zimbabwe. Small grains are drought tolerant and perform better in dry regions than any other cereal crops. Sorghum and millet have the potential to contribute to food security to the world's poorest agro-ecological regions.

Keywords: Climate change; Food security; Small grain; Climate compliant; Productivity.

1. Introduction

Inadequate and poor rainfall distribution in most dry regions in sub-Saharan Africa has contributed to low and poor crop production leading to food insecurity. Low crop productivity in most of these regions has been attributed to low rainfall, moisture stress, infertile soils and increased land degradation [1, 2]. Most farmers in dry regions experience drought and long dry spell which contributed to food insecurity [3]. The situation has been worsened by climate change in these dry regions affecting most of the countries in southern Africa particularly Zimbabwe. Climate change is predicted to make Zimbabwe drier and have higher temperatures [4, 5]. Food production will seriously be affected despite technological advancement in plant breeding, fertiliser and irrigation systems [5]. The poor and vulnerable will be the most susceptible to changes in climate especially those who rely on rain fed agriculture for their livelihoods [6, 7]. The issue of climate change brought in issues of total crop failure in dry regions in Zimbabwe as evidenced by total crop failure in 2010, 2015 and 2017 in some parts of Chivi which is one of the driest area in Zimbabwe. This brings in an idea of growing small grain by farmers as means of improving food production in dry areas such as Chivi, Mwenezi and Chiredzi districts.

Cereal production growth in Sub-Saharan Africa is expected to decline by a net 3.2 percent in 2050 as a result of climate change. Under climate change scenarios, climate change act as a stressor on the tightening price increases. Maize, rice and wheat prices are projected to be 4, 7 and 15 percent higher [8]. Prices of crops such as sweet potatoes, and yams by 26 percent, cassava by 20 percent, millet by 5 percent and sorghum by 4 percent [9]. Mugiya and Hofisi [10] highlighted that recurrent climate changes will results in shifts of agro-ecological regions and high temperatures are expected to shorten the growing season by 2 to 35 days. Climate change will result in Zimbabwe being declared a non-maize producing zone a situation which will promote food insecurity [10]. This makes adaptation a necessity by bringing in small grains (sorghum, millet and rapoko) in order to enhance food security against the change in climate [11-14].

Several studies have indicated a change in production trends of the small grain for the past 14 years [13, 15-17]. There is need to increase productivity of small grains in Zimbabwe in order to ensure nutrition and food security as they are well adapted to changing climate [17-19]. The use of small grains such as sorghum and millet as means of improving food security in dry regions has been an issue for the past decades but most farmers were resisting the idea. Small grains are drought tolerant and perform better in dry regions than any other cereal crops. According to FAO and ICRISAT [20] in Masara [21] sorghum and millet have the potential to contribute to food security to the world's poorest agro-ecological regions. To mitigate this risk, there is need to improve productivity of small grains as climate compliant crops which can ameliorate poverty in Zimbabwe.

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2. Impact of Climate Change on Food Security in Zimbabwe

Food security occurs when all people at all times have access to sufficient nutritious food which meet their dietary requirements for them to be active and have a healthy life [22]. Climate change in Africa is expected to reduce crop yields and successively increase the price of food that will force people to alter consumption and production patterns [23]. Sub-Saharan Africa was expected that it will expertise higher probabilities in terms of vulnerability to food security [22, 24]. Studies by Schmiduber and Tubiello (2007) cited by Masipa [22] distinguished that an estimate of between 5 and 170 million people are going to be in danger of hunger by year 2080cited by Masipa [22] pointed out that an estimate of between 5 and 170 million people will be at risk of hunger by year 2080. It is very clear that climate change presents a high risk on food security. Svodziwa [25], postulated that temperature change has exaggerated semi-arid areas in Republic of Zimbabwe thereby reducing maize production areas.

Production of staple food has been declining since early 90s in Zimbabwe bringing in food insecurity problems [26, 27]. Household food security in Zimbabwe has been declining due to drastic reduction in agricultural production and erratic rains [27, 28]. Food security in Zimbabwe continues to decline in the face of drought, acute foreign currency and hyperinflation [28, 29].

2.1. Why Small Grains in Zimbabwe as Climate Compliant Crops?

Alumira and Rusike [30] highlighted that small grains can reduce zero probability of yields thereby ensuring food security. Barrett and Maxwell [31] highlighted that small grains are better performers than most cereals under harsh environmental conditions viewed unsuitable for maize. Small grains are generally the most drought tolerant cereal grain crops requiring little input during growth and with decreasing water supplies as noted by Bang and Sitango [32]. Dube [33] pointed out that a meal cooked from the small grains is able to satisfy hunger for a longer period and gives more energy. The country is vulnerable to climate variation as a result of the maize crop's sensitivities to climate change as it takes approximately 80-90% of area under production [34, 35].

2.2. Finger Millet (*Eleusine Coracana* Gaertn)

Finger millet is highly nutritive, climate resilient crop which can is hardy and shows quick rejuvenating capacity to abiotic and biotic stresses [36]. Finger millet contain high levels of amino acids absent in most staple cereal crops resulting in it being highly nutritious. It has got high levels of iron and micronutrients which are an essential component of diet for pregnant women and children. Polyphenols and the dietary fibers have several health benefits. Regular consumption of finger millet regulate glucose homeostasis and prevention of dyslipidaemia [37]. This small grain is naturally resistant to insect pests and has got longer storage life [21].

2.3. Sorghum (Sorghum *Bicolor* L.)

Sorghum is ranked fifth important cereal crop in the world [38, 39]. Sorghum is a drought tolerant and is resistant to waterlogging and grows in various soil conditions [40-42]. In Africa sorghum is the second important cereal crop after maize especially for semi-arid and arid regions where it is used as one of the staple food [13, 39, 43]. Sorghum production has been very low but widely adopted by smallholder farmers in arid and semi-arid regions [39]. Adoption of sorghum by most people in arid and semi-arid regions as one of their staple cereal crop has brought hope to improving food security in these regions. It is adopted by farmers in these regions because it thrive well in drought, low fertility and high temperature regions and low input requirements [44]. Sorghum production was very low with most farmers harvesting 520 kg/ha on average [43] which is very low to sustain a family for a year. This makes a lot of farmers to shift from sorghum production and concentrated on maize production but still the production was very low due to climate change and poor soil fertility. Increasing hacterage of sorghum by farmers has been witnessed as a good idea of improving its production for family consumption. Farmers also adopted sorghum for many reasons including beer brewing and feeding livestock. It can be processed using technologies of dry and wet milling applied to maize due its hard and floury endosperm and large fat rich gem [13]. Sorghum is inherently gluten free which is a good attribute for people with celiac disease (Ciacci *et al*., 2007) as cited by Omoro [45].

2.4. Pearl Millet (*Pennisetum Glaucum* L.)

Pearl millet is ranked as a 6th crop after wheat, rice, maize, sorghum and barley grown on area of 31 million ha [46]. The crop is culturally appropriate, ecologically suitable, nutritionally efficacious and economically viable as highlighted by Ndiku, *et al.* [47]. It is considered as main component of food security of rural people in hot and dry areas in the world including Zimbabwe [48]. Khairwal, *et al.* [49] mentioned that pearl millet is a main source of energy, protein, vitamins/amino acids (except lysine and threonine) and mineral for poorest people of hot and dry areas. Studies indicated that pear millet is a rich source of phytochemicals and micronutrients [50, 51]. It contains about 92.5% dry matter, 2.15 ash, 2.8 crude fiber, 7.8% crude fat, 13.6% crude protein and 63.2% starch. Pearl millet is one of the most important cereal crop in Zimbabwe although its production is low in high rainfall areas and mainly grown in drier areas of the country as means of improving food security.

2.5. Improving Small Grain Production to Meet Food Demand in Arid and Semi-Arid Regions

Low crop productivity in dry regions has been associated with moisture stress, low incomes, land constraints and climate change in Zimbabwe [52, 53]. This has been a great problem for rainfed agriculture in Zimbabwe since most farmers are poor resource and their soils have low weatherable minerals [54] causing the soils to be inherently infertile. Land degradation has also increased due to heavy downpours and poor soil cover which exposes soil to soil erosion and loss of nutrients. There is need for soil and water conservation [55] as means of improving small grain production in dry region to meet food security demands, improved nutrition and zero hunger. The use of soil and water conservation can be a useful option to boost food small grain production in low rainfall areas. Since these areas have frequent droughts and low midseason dry spell, the use of rainwater harvesting [56, 57] and integrated nutrient management [39, 58] can be an option to increase soil fertility, reduce moisture stress and improve sorghum and millet production.

Rainwater harvesting has been seen as best way of harvesting water for future use by crops, reduce surface runoff, increase moisture in the plant root zone and reducing moisture stress to crops during the dry spell [55, 57]. A variety of rainwater harvesting such as insitu rainwater harvesting and field edge rainwater harvesting can be used. Insitu rainwater harvesting like tied ridging, potholing, zai pitting and circular bunds have been reported to reduce surface runoff in arable lands and increase moisture availability in plant root zone [56]. According to Kimaru [39] rainwater harvesting alone cannot improve crop yields but there is need to combine with integrated nutrient management options. Since smallholder farmers are resource poor [54], that is, they are not able to buy large quantities of mineral fertiliser, there is need to combine use of mineral fertiliser with cattle manure and farm yard manure which is readily available in smallholder farmers in dry regions. According to Mwadalu [59] the use of farm yard manure with inorganic fertiliser improved soil physio biochemical properties and improved sorghum yields. Mohsin, *et al.* [60] reported that the integrated use of farmyard manure and reduced rates of mineral fertiliser is the best sustainable option which improves soil health and crop production. Mwangi, *et al.* [61] reported an increase in maize yields after the use of farm yard manure as soil amendment and this can be applicable to sorghum production in Zimbabwe if implemented appropriately as means of improving small grain production with particular attention to sorghum and millet.

Table-1. Effects of integrated nutrient management and rainwater harvesting from selected countries

Integrated nutrient management options	Rainwater harvesting techniques	Grain yield (t/ha)		Country and rainfall (mm)	Journal	Reference
		Sorghum	Pearl millet			
Inorganic fertiliser + poultry manure	N/A	3.55		Nigeria; 795.6	African journal of biotechnology	Amujoyegbe, *et al.* [62]
45kg N + 2 t cattle manure	N/A	4.04		Nigeria; ------	GSC Biological and Pharmaceutical Sciences	Shuaibu, *et al.* [63]
100kg/ha NPK + 2.5 t cattle manure	Strip cropping		0.905	Niger; 621	Kwame Nkrumah University of Science and Technology	Gonda [64]
200kg/ha NPK + 2.5 t cattle manure	Strip cropping		1.395	Niger; 621	Kwame Nkrumah University of Science and Technology	Gonda [64]
100kg/ha NPK + 5 t cattle manure	Strip cropping		1.347	Niger; 621	Kwame Nkrumah University of Science and Technology	Gonda [64]
200kg/ha NPK + 2.5 t cattle manure	Strip cropping		0.918	Niger; 621	Kwame Nkrumah University of Science and Technology	Gonda [64]
41 kg/ha N + 46kg/ha P_2O_5 + 2.5 t cattle manure	Tied ridging		1.37	Mali; 560	Kwame Nkrumah University of Science and Technology	Coulibaly [65]
41 kg/ha N + 46kg/ha P_2O_5 + 2.5 t cattle manure	Tied ridging		1.716	Mali; 742	Kwame Nkrumah University of Science and Technology	Coulibaly [65]
5t Cattle manure + 30 kg/ha N	Planting pits	3.98		Zimbabwe; 420	Global Scientific Journal	Kugedera, *et al.* [43]
5t Cattle manure + 30 kg/ha N	Tied ridging	3.94		Zimbabwe; 420	Global Scientific Journal	Kugedera, *et al.* [43]
100kg/ha NPK + 2.5 t cattle manure	Strip cropping		0.866	Niger; 374	Kwame Nkrumah University of Science and Technology	Gonda [64]
200kg/ha NPK + 2.5 t cattle manure	Strip cropping		0.647	Niger; 374	Kwame Nkrumah University of Science and Technology	Gonda [64]
100kg/ha NPK + 5 t cattle manure	Strip cropping		0.716	Niger; 374	Kwame Nkrumah University of Science and Technology	Gonda [64]
200kg/ha NPK + 2.5	Strip		0.665	Niger; 374	Kwame Nkrumah	Gonda [64]

t cattle manure	cropping				University of Science and Technology	
5t Cattle manure + 30 kg/ha N	Zai pits	1.9		Kenya; 250	Kenyatta University	Kimaru [39]
5t Tithonia + 30 kg/ha N	Zai pits	2.5		Kenya; 250	Kenyatta University	Kimaru [39]
5t Cattle manure +	Zai pits	1.1		Niger	Ecology and Development series	Fatondji [66]
Crop rotation+ cattle manure	Tied ridges	1.8		Mali	African Journal of Agricultural Research	Kouyaté, *et al.* [67]
5t Cattle manure + biomass transfer	N/A		0.607	Zimbabwe, 350	International Journal of Agriculture and Agribusiness	Kugedera and Kokerai [68]
5t cattle manure + 100kgN/ha	N/A		0.62	Zimbabwe, 350	International Journal of Agriculture and Agribusiness	Kugedera and Kokerai [68]

2.6. Future Prospects

There is need to implement integrated nutrient management and rainwater harvesting techniques as means of improving small grain productivity in dry regions of Zimbabwe. Results in Table 1 show various integrated nutrient management and rainwater harvesting techniques which can be adopted by smallholder farmers as means of improving small grains and food security. There is need to carry out a lot of demonstrations and farmer training on integrated nutrient management and rainwater harvesting to increase their adoption. Farmers need to be taught on how to use the readily available sources of nutrients such as cattle manure, goat manure and farmyard manure and integrated with low quantities of inorganic fertilisers especially Nitrogen fertilisers. Farmers need to be taught these rainwater harvesting as means of soil and water conservations so that their adoption can be increased and there is need for government to intervene through Ministry of Agriculture so that the programme can be quickly recognised by farmers. More researches also need to be done in different regions.

3. Conclusion

The country is vulnerable to climate variation as a result of the maize crop's sensitivities to climate change. Climate change will result in Zimbabwe being declared a non-maize producing zone a situation which will promote food insecurity. Small grains are generally the most drought tolerant cereal grain crops requiring little input during growth and perform better in dry regions with decreasing water supplies. The use of integrated nutrient management and rainwater harvesting has been seen to increase small grain production in various countries and this can also be a way of reducing poverty and food insecurity in dry regions of Zimbabwe.

Recommendations

Integration of various nutrient management options and rainwater harvesting such as in situ rainwater harvesting and field edge rainwater harvesting can be used to increase small grains crop yields in semi-arid areas. The use of soil and water conservation can be a useful plant to boost food small grain production in low rainfall areas. There is need to increase productivity of small grains in Zimbabwe in order to ensure nutrition and food security as they are well adapted to changing climate.

References

[1] Muchai, S. W. K., Ngetich, F. K., Baaru, M., and Mucheru-Muna, M. W., 2020. "Adoption and utilisation of Zai pits for improved farm productivity in drier upper Eastern Kenya." *J. Agr. Rural Develop. Trop. Subtrop.*, vol. 121, pp. 13-22.

[2] Njeru, P., Mugwe, J., Maina, I., Mucheru-Muna, M., Mugendi, D., Lekasi, J., Kimani, S., Miriti, J., Oeba, V., *et al.*, 2015. *Integrating farmers and scientific methods for evaluating climate change adaptation options in Embu county, adapting African agriculture to climate change*. Nederlands: Springer. pp. 185-197.

[3] Ayanlade, A., Radeny, M., Morton, J. F., and Muchaba, T., 2018. "Rainfall variability and drought characteristics in two agro-climatic zones: An assessment of climate change challenges in Africa." *Science of the Total Environment*, vol. 630, pp. 728-737.

[4] Makadho, J. M., 1996. "Potential effects of climate on corn production in Zimbabwe." *Climate Research*, vol. 6, pp. 147-151.

[5] Simba, F. M., Chikodzi, D., and Murwendo, T., 2012. "Climate change scenarios, perceptions and crop production: A case study of semi-arid masvingo province in Zimbabwe." *J. Earth Sci. Climate Change*, vol. 3, p. 124.

[6] International Resources Group, 2008. "Impacts of climate change on rural livelihoods in Madagascar and the potential for adaptation." Available: http://pdf.usaid.gov/pdf_docs/PNADP632

[7] Nzeadib, T. C., Egbule, C. L., Chukwuone, N. A., and Agu, V. C., 2011. "Climate change awareness and resilient adaptation: Indigenous drivers of regional sti policy in Niger Delta, the first climate change and development in Africa." In *Conference Paper*.

[8] Ringler, C., Zhu, T., Cai, X., Koo, J., and Wang, D., 2017. "Climate change impacts on food security in Sub-Saharan Africa insights from comprehensive climate change modeling." *International Food Policy Research Institute*, pp. 15-20. Available: www.cosv.org/.../climate%20change%20impacts%20on%20food%20security

[9] Deressa, T. T., Hassan, R. M., and Ringler, C., 2011. "Perception and adaptation to climate change by farmers in the Nile basin of Ethiopia." *Journal of Agricultural Science*, vol. 149, pp. 23-31.

[10] Mugiya, D. and Hofisi, C., 2017. "Climate change adaptation challenges confronting small-scale farmers." *Environmental Economics*, vol. 8, pp. 57-65.

[11] Gukurume, S., 2010. "Farming and the food security-insecurity matrix in Zimbabwe: A case of ward 21 Chivi rural." *Journal of Sustainable Development in Africa*, vol. 12, pp. 40-52.

[12] Phiri, K., Dube, T., Moyo, P., Ncube, C., Ndlovu, S., and Buchenrieder, G., 2019. "Small grains “resistance”? Making sense of Zimbabwean smallholder farmers’ cropping choices and patterns within a climate change context." *Cogent Social Sciences*, vol. 5, p. 1622485. Available: https://doi.org/10.1080/23311886.2019.1622485

[13] Taylor, J. K. N., 2003. "Overview: Importance of Sorghum in Africa. In: Afripro: Workshop on the proteins of sorghum and millets: Enhancing nutritional and function properties for Africa. Eds. P.S. Belton and j. R. N. Taylor. Pretoria, 204 april, 2003, paper, 01." Available: www.africipro.org.uk

[14] FAO and ICRISAT, 2008. "Special report on crop and food supply assessment mission to Zimbabwe 18 June 2008." Available: www.fao.org/docrep/010/ai469e/ai469e00.htm

[15] Chanza, N., 2018. *Limits to climate change adaptation in Zimbabwe: Insights, experiences and lessons*. Cham: Climate Change Management. Springer.

[16] Gukurume, S., 2013. "Climate change, variability and sustainable agriculture in Zimbabwe’s rural communities, Russian." *Journal of Agricultural and Socio- Economic Sciences*, vol. 2, pp. 89-93.

[17] Nhemachena, C., Mano, R., Mudombi, S., and Muwanigwa, V., 2014. "Climate change adaptation for rural communities dependent on agriculture and tourism in marginal farming areas of the Hwange District, Zimbabwe." *African Journal of Agricultural Research*, vol. 9, pp. 2045-2054.

[18] Matthew, S., 2015. "The feasibility of small grains as an adoptive strategy to climate change." *Russian Journal of Agricultural and Socio-Economic Sciences*, vol. 4, pp. 40-55.

[19] Ndlovu, S., Mpofu, M., and Moyo, P., 2019. *Debunking the effectiveness of in-kind transfers in alleviating urban household food insecurity in Bulawayo*. Zimbabwe: Development Southern Africa. pp. 1-15.

[20] FAO and ICRISAT, 1996. *The world sorghum economies: Facts, trends and outlook*. Rome, Italy and Andhra Pradesh, India: FAO, ICRISAT.

[21] Masara, W. B., 2015. *The return of small grain crop production in semi-arid parts of Zimbabwe through Aid gave rural people hope. Discussing the contribution of small grains in reducing rural poverty in semi-arid Zimbabwe*. University of Zimbabwe.

[22] Masipa, T. S., 2017. "The impact of climate change on food security in South Africa: Current realities and challenges ahead’, Jàmbá." *Journal of Disaster Risk Studies*, vol. 9, p. a411. Available: https://doi.org/10.4102/jamba.v9i1.411

[23] European Commission, 2009. *Food security: Understanding and meeting the challenges of poverty*. Luxembourg: Publications Office of the European Union.

[24] Vogel, C., 2005. "Usable Science: An assessment of long-term seasonal forecasts among farmers in rural areas of South Africa." *South African Geographical Journal*, vol. 82, pp. 107-116. Available: https://doi.org/10.1080/03736245.2000.9713700

[25] Svodziwa, M., 2015. "The feasibility of small grains as an adoptive strategy to climate change." *Russian Journal of Agricultural and Socio-Economic Sciences*, vol. 5, pp. 40-55. Available: https://doi.org/10.18551/rjoas.2015-05.04

[26] Jayne, T. S., Chisvo, M., Rukunni, M., and Masanganise, P., 2006. *Zimbabwe’s food insecurity paradox hunger amid potential. In: Eds. Rukuni, m,tawonezvi, p, eicher, c, munyuki-hungwe, m. And matondi*. Harare, Zimbabwe.: Zimbabwe’s Agricultural Revolution Revisited, University of Zimbabwe Publications.

[27] Mukarumbwa, P. and Mushunje, A., 2010. "Potential of sorghum and Finger millet to enhance household food security in Zimbabwe’s semi-arid regions. A Review." In *Contributed paper presented at the Joint 3rd African Association of Agricultural Economica (AAAE) and 48th Agricultural Economists Association of South Africa (AEASA) Conference, Cape Town, South Africa, September 19-23, 2010.*

[28] FAO/WFP, 2008. "Special report crop and food supply assessment mission to Zimbabwe 18 june 2008." Available: http://www.fao.org/docrep/010/ai469e/ai469e00.htm

[29] FEWSNET, F. E. W. S. N., 2008. "Zimbabwe food security outlook october 2007 to march 2008." Available: http://www.fews.net/docs/Publications/Zimbabwe200708en.pdf

[30] Alumira, J. and Rusike, J., 2005. "The green revolution in Zimbabwe." *Journal of Agricultural and Development Economics*, vol. 2, pp. 50-66.

[31] Barrett, C. B. and Maxwell, D. G., 2005. *Food aid after fifty years: Recasting its role*. New York: Routledge.

[32] Bang, S. K. and Sitango, K., 2003. "Indigenous drought coping strategies and risk management against el nino in Papua New Guinea: CGPRT centre working paper No. 74."

[33] Dube, C., 2008. *The impact of Zimbabwe”s drought policy on Sontala rural community in Matabeleland South Province. MSc Thesis*. Department of geology, Geography and environmental studies; Stellenbosch University.

[34] Muzerengi, T. and Tirivangasi, H. M., 2019. "Small grain production as an adaptive strategy to climate change in Mangwe District, Matabeleland South in Zimbabwe, Jàmbá." *Journal of Disaster Risk Studies,* vol. 11, p. a652. Available: https://doi.org/10.4102/jamba.v11i1.652

[35] Zimbabwe Human Development Report, 2017. Available: http://hdr.undp.org/sites/default/files/reports/2842/undpzw2017zhdrfull.pdf

[36] Sasmal, A., Mohapatra, A. K. B., and Pradhan, K. C., 2018. "Screening of finger millet genotypes against pink stem borer, Sesamia inferens Walker, Noctuidae, Lepidoptera." *Journal of Entomology and Zoology Studies,* vol. 6, pp. 796-799.

[37] Devi, P. B., Vijayabharathi, R., Sathyabama, S., and Priyadarsini, V. B., 2010. "Health benefits of finger millet (*Eleusine coracana* L.) polyphenols and dietary fibre: A review." *Journal of Food Science and Technology,* vol. 47, p. 19.

[38] FAO, 2018. "Food and agricultural organisation of the united nations faostatistics data base." Available: http://www.fao.org/faostat/en/#data/QCProductionofselectedcerealcrops

[39] Kimaru, S. W., 2017. *Zai pits and integrated soil fertility management enhances crop yields in the drier parts of Tharaka Nithi county, Kenya. PhD thesis*. Kenya: Kenyatta University.

[40] Dillon, S. L., Shapter, F. M., Henry, R. J., Cordeiro, G., Izquierdo, L., and Lee, L. S., 2007. "Domestication to crop improvement: Genetic resources for sorghum and saccharum, andropogoneae." *Annals of Botany,* vol. 100, pp. 975-989.

[41] Doggett, H., 1988. *Sorghum.* 2nd ed. UK: Tropical Agricultural Series. Longman Scientific, Essex.

[42] Muui, C., Muasya, R. M., Nguluu, S., Kambura, A., Kathuli, P., Mweu, B., and Odhiambo, D. O., 2019. "Sorghum landrases production practices in Nyanza, Coast and Eastern regions, Kenya." *Journal of Economics and Sustainable Development,* vol. 10, pp. 134-143.

[43] Kugedera, A. T., Kokerai, L. K., and Chimbwanda, F., 2018. "Effects of insitu rainwater harvesting and integrated nutrient management options on Sorghum production." *Global Scientific Journals,* vol. 6, pp. 415-427.

[44] Mwadalu, R. and Mwangi, M., 2013. "The potential role of sorghum in enhancing food security in Semi-Arid eastern Kenya: A review." *Journal of Applied Biosciences,* vol. 71, pp. 5786-5799.

[45] Omoro, W., 2013. *Factors for low sorghum production: A case study of small-scale farmers in east Kano sub location, Nyando District, Kenya, a research project submitted to Van Hall Larenstein University of applied sciences in partial fulfilment of the requirements for the degree of master of development*. Specialization: Rural Development and Food Security.

[46] ICRISAT, 2016. "Pearl millet." Available: http://exploreit.icrisat.org/page/pearlmillet/680/274

[47] Ndiku, M. H., Jara, E., and Sabate, J., 2014. "Formative research on acceptability of pearl millet in rural eastern Kenya – A pilot study." *Sustainable Agriculture Research,* vol. 3, pp. 1-8.

[48] Vadez, V., Berger, J. D., Warkentin, T., Asseng, S., Ratnakumar, P., Rao, K. P. C., Gaur, P. R., Munier-Jolai, N., Lamure, A., *et al.*, 2012. "Adaptation of grain legumes to climate change: A review." *Agronomy Sustainable Development,* vol. 32, pp. 31-44.

[49] Khairwal, I. S., Rai, K. N., Diwakar, B., Sharma, Y. K., Rajpurohit, B. S., Bindu, N., and Ranjana, B., 2007. *Growth and development of Pearl millet plant*. Andhra Pradesh, India: International Crops Research Institute for the Semi-Arid Tropics. p. 104.

[50] Saleh, A. S. M., Qing, Z., Jing, C., and Qun, S., 2013. "Millet grains: nutritional quality, processing and potential health benefits." *Comprehensive Reviews in Food Science and Food Safety,* vol. 12, pp. 281-295.

[51] Singh, P. and Raghuvanshi, R. S., 2012. "Finger millet for food and nutritional security." *African Journal of Food Sciences,* vol. 6, pp. 77-84.

[52] Masvaya, E. N., Nyamangara, J., Descheemaeker, K., and Giller, K. E., 2017. "Tillage, mulch and fertiliser impacts on soil nitrogen availability and maize production in semi-arid Zimbabwe." *Soil and Tillage Research,* vol. 168, pp. 125–132. Available: http://dx.doi.org/10.1016/j.still.2016.12.007

[53] Mupangwa, W., Twomlow, S., and Walker, S., 2012b. "Reduced tillage, mulching and rotational effects on maize (*Zea mays* L.), cowpea (*Vigna unguiculata* (Walp) L.) and sorghum (*Sorghum bicolor* (Monoench)) yields under semi-arid conditions." *Field Crops Research,* vol. 132, pp. 139-148.

[54] Chikowo, R., 2004. *Nitrogen cycling in agroforestry systems of Sub-humid Zimbabwe: A closing loop. PhD Thesis*. The Netherland: Wageningen University.

[55] Nyamadzawo, G., Gotosa, J., Moyo, F., and Govere, I., 2016a. "The potential of tied contours and crop intensification and on maize yields in semi-arid smallholder farming area of marange, Zimbabwe." In *RIOSET conference, Bulawayo, Zimbabwe.*

[56] Mudatenguha, F., Anena, J., Kiptum, C. K., and Mashingaidze, A. B., 2014. "In situ rain water harvesting techniques increases maize growth and grain yield in a semi-arid agro-ecology of Nyagatare, Rwanda." *Int. J. Agric. Biol.,* vol. 16, pp. 996-1000.

[57] Nyamadzawo, G., Wuta, M., Nyamangara, J., and Gumbo, D., 2013. "Opportunities for optimizing infield water harvesting to cope with changing climate in semi-arid smallholder farming areas of Zimbabwe." *Springer Plus,* vol. 2, pp. 1-9.

[58] Mugwe, J. N., 2007. *An evaluation of integrated soil fertility management practices in Meru south district, Kenya. DPhil thesis*. Kenyatta University.

[59] Mwadalu, 2014. *Improving sorghum grain yield through use of mineral fertilizers and farm yard manure for smallholder farmers in Makueni and Machakos counties. Msc Thesis*. Kenya: Kenyatta University. p. 117.

[60] Mohsin, A. U., Ahmad, J., Ahmad, A. U. H., Ikram, R. M., and Mubeen, K., 2010. "Effect of nitrogen application through different combinations of urea and farmyard manure on the performance of spring maize." *Journal of Animal and Plant Science,* pp. 195-198.

[61] Mwangi, T. J., Moebe, S. N., Wanjekenche, E., Onyango, R., Ngeny, J., and Osore, Z., 2010. "Improving and sustaining soil fertility by using farmyard manure and inorganic fertilizer for economical maize production in West Pokot, Kenya." *World Journal of Agricultural Sciences,* vol. 6, pp. 313-321.

[62] Amujoyegbe, B. J., Opabode, J. T., and Olayinka, A., 2007. "Effect of organic and inorganic fertilizer on yield and chlorophyll content of maize (*Zea mays* L.) and sorghum *Sorghum bicolour* (L.) Moench)." *African Journal of Biotechnology,* vol. 6, pp. 1869-1873.

[63] Shuaibu, Y. M., Bala, R. A., Kawure, S., and Shuaibu, Z., 2018. "Effect of organic and inorganic fertilizer on the growth and yield of sorghum (*Sorghum bicolor* (L.) Moench) in Bauchi state, Nigeria." *GSC Biological and Pharmaceutical Sciences,* vol. 2, pp. 25-31.

[64] Gonda, A., 2015. *Integrated management of composted cattle manure and mineral fertilizer for improved pearl millet and cowpea yields under strip cropping system in Niger. PhD thesis*. Ghana: Kwame Nkrumah University of Science and Technology. p. 185.

[65] Coulibaly, B., 2015. *Impact of water harvesting techniques and nutrient management options on the yield of pearl millet in the Sahelian Zone of Mali. PhD thesis*. Ghana: Kwame Nkrumah University of Science and Technology. p. 193.

[66] Fatondji, D., 2002. *Organic amendment decomposition, nutrient release and nutrient uptake by millet (Pennisetum glaucum L. R. Br) in a traditional land rehabilitation technique (zai) in the Sahel, 2002. PhD dissertation*. Nick van de Giesen: Ecology and development Series No. 1 2002. Eds: Paul L. Vlek, Manfred Denich, Christopher Martius.

[67] Kouyaté, Z., Diallo, D., N'Diaye, K., and Ayemou, A., 2012. "Influence of crop management systems on soil properties and sorghum yields in the Sahelian zone of Mali." *African Journal of Agricultural Research,* vol. 7, pp. 5217-5223.

[68] Kugedera, A. T. and Kokerai, L. K., 2019. "Role of biomass transfer and integrated nutrient management in improving soil fertility and pearl millet yields." *International Journal of Agriculture and Agribusiness,* vol. 2, pp. 115-121.