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Need for sustainable solution: Environment, rural agriculture and food security affected by electronic waste pollution of streams and Sakubva River

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Abstract

Electronic waste is currently the largest growing waste stream in the world. It is hazardous, complex and expensive to treat in an environmentally sound manner. Unsustainable electronic waste management of has led to pollution of rivers, which has negatively affected the environment, agriculture activities and food security. The research sought to investigate the waste management of electronic waste, its impact on environment, agriculture and food security in the rural communities. To recommend sustainable waste management strategy for the country and reduce the adverse effects on environment and agriculture to enhance food security. Zimbabwe has become an electronic waste hazard as waste pile up at backyard and in houses. A research survey was conducted in Mutare urban and peri-urban rural communities involving a sample of 1250 participants revealed that 29% of waste was electronic effluent, 29% of waste in backyard, 22% of waste in storerooms. The peri-urban rural communities are heavily affected downstream as the Sakubva River and its streams are polluted, either poisoned or drying up. Methods of disposal were landfilling, burning, backyard and storeroom storage. Food security as a state where the availability, accessibility, utilization and stability of food are ensured and food production is enough to cover the food demand of the people has been heavily affected as water for gardening and field crop irrigation is polluted. It was revealed that in some areas farmers have totally stopped gardening as the source of water has dried up due to both soil and water pollution.

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Introduction

The United Nations (2008) defines food security as a state where the availability, accessibility, utilization and stability of food are ensured and food production is enough to cover the food demand of the people. FAO (2010) reviewed that despite the fact that more than enough food was being produced per capita to adequately feed the global population, about 925 million people remained food insecure in 2010. Abalansa *et al.* (2021) indicated that electronic waste is a rapidly developing environmental problem particularly for the most developed countries that has negatively affected the sustainable agriculture practices for food security. Electronic waste are various forms of electric and electronic equipment that have ceased to be of value to their users or no longer satisfy their original purpose (Gill, 2021). The electronic waste products have exhausted their utility value through either redundancy, replacement, or breakage and this include both "white goods" such as refrigerators, washing machines, and microwaves and "brown goods" such as televisions, radios, computers, and cell phones (Gill, 2021). Electronic waste is considered the "fastest-growing waste stream in the world" (WEF, 2019) with 44.7 million tonnes generated in 2016- equivalent to 4500 Eiffel towers Balde *et al.* (2017). In 2018, an estimated 50 million tonnes of electronic waste was reported, thus the name 'tsunami of electronic waste' given by the United Nations (WEF, 2019). Its value is at least $62.5 billion annually (WEF, 2019).

The world currently has a variety of environmental problems resulting from manufacturing activities, including plastic pollution and electronic waste. Plastic pollution can be traced back to the beginning of the commercial production of plastics in the 1950s (Barnes *et al.*, 2009), but more recently, electronic waste is considered an emerging environmental problem (Saldana-Duran *et al.*, 2020). The sources of the majority of these can be traced to major developed countries, although there is an increasing contribution from rapidly developing countries like China and India. The Basel Convention was formulated to ensure that environmental problems are not exported across boundaries (Choksi, 2001; Ogunseitan, 2013; Kummer, 1992). Developed countries have state-of-the-art facilities, finances and technology to handle waste (Forti *et al.*, 2020). However, much of the electronic waste is not recycled but exported to developing countries (Illes and Geeraerts, 2016), which are already struggling with economic problems such as poverty. Many factors contribute to this surge in electronic waste. These include the short lifecycle of equipment, low recycling (Rabani and Thakur, 2020), and the continuous upgrading of electronic equipment (Wang *et al.*, 2019) as affluent societies demand the latest technology. Electronic waste has been described as one of most difficult classes of waste to manage due to a constant change in its features and specificities (Borthakur and Singh, 2020). Recently, Zimbabwe has also been become an electronic waste hazard as electronic equipment are piling up very fast in company offices and in houses. Electronic scrap components, such as central processing units, contain potentially harmful materials such as lead, cadmium, beryllium, or brominated flame-retardants. Recycling and disposal of electronic waste may involve significant risk to health of workers and their communities (Sakar, 2016). According to the Basel Convention (1989) on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal of 1989, Art. 2(1), "'Wastes' are substance or objects, which are disposed of or are intended to be disposed of or are required to be disposed of by the provisions of national law" (Basel Convention, 1989). Under the Waste Framework Directive 2008/98/EC, Art. 3(1), the European Union defines waste as "an object the holder discards, intends to discard or is required to discard."(EPC, 2008).

In 2000, Zimbabwe moved a gear up to introduce use of high electronic technology mainly computers. The country received several donations of digital electronic equipment including computers, printers and digital instruments. However, as the old type writers, calculators and till machines and banking machine were replaced with the new electronic equipment, waste management became a challenge. Electronic waste was created as the old electronic products were discarded along the years, as it was believed that they had attained end of their useful life. The rapid expansion of technology and the consumption driven society results in the creation of a very large amount of electronic waste in the back yard, storerooms and in the spare rooms at homes. There are several pieces of legislation in place pertaining to litter and waste management. Electronic waste management in Zimbabwe is guided by the EMA, Chapter 20:27. Section 70 (1) of the EMA Act which stipulates that 'No person shall discharge or dispose any waste in a manner that causes environmental pollution or ill health to any person' (EMA, 2002). Thus, it follows that according to the EMA Act, any person whose activities generate waste is mandated to use measures to minimise the waste through treatment, reclamation and recycling, among others. Mihaela (2014) revealed that there is an interdependence, between sustainable agriculture practice concepts and food security. The downstream communities in the peri urban of Muatre require water for agricultural activities, which has been heavily affected by pollution upstream, hence, food security is also heavily affected downstream. Hamid, (2019) indicated that the main outcome of sustainable agriculture practices is food security.

Nevertheless, about half of the global population is affected by food insecurity and malnutrition, a symptom of the dysfunctions of the current food system (Hamid, 2019) as the land, soil, water and air are polluted by waste. Therefore, since Zimbabwe moved a gear up to introduce use of high electronic technology mainly computers. The improper management and disposal of the electronic waste from the old electronic products along the years as resulted into pollution of the dumping sites, rivers and streams. The pollution has heavily affected the agriculture activities and the communities downstream is now food insecure. The research sought to investigate the waste management of electronic waste, the impact of the electronic pollution on agriculture and food security in the study area. This was done to recommend sustainable waste management strategy for the country and reduce the effects of pollution on environment and agriculture in order to enhance food security.

Research methodology

Research questions

i. What is the disposable waste management mechanism in place to manage the electronic waste introduced by of high use of electronic technology?
ii. What are the characteristics of the electronic waste and where are they stored in the study area?
iii. What is the impact of the electronic waste pollution on environment, agriculture activities and food security in the study area?
iv. What are the possible strategies for electronic waste management to reduce adverse impacts on environment agriculture and food security in the study area?

Specific objectives of the study

i. To identify the disposable management mechanism for the electronic waste being generated by of high use of electronic technology
ii. To establish the characteristics of the electronic waste and where are they stored in the study area.
iii. To assess the impact of the electronic waste pollution on environment, agriculture activities and food security.
iv. To recommend possible strategies for electronic waste management to reduce adverse impacts on environment agriculture and food security.

Research design, population and sample

The research was conducted in Mutare urban and the peri-urban rural communities. The researcher used both positivist and intrepretivist paradigm approaches but largely remained qualitative because the approach provides high data reliability, openness and flexibility. Used descriptive design through a survey to gather both qualitative and quantitative data. The targeted population was 668 organisation found in the urban industrial site and 4256 households. Probability and non-probability sampling procedures were applied, through stratified sampling, the user of electronic equipment were grouped into organisations and households. Thereafter simple random sampling was used to select 200 organisations, convince sampling was applied to select 300 homes, and purposive sampling was used to identify 150 key informants, thereby bringing the total sample of 650 participants. The targeted population for the per-urban rural communities was 1884 households. Probability and non-probability sampling procedures were applied, through stratified sampling, the households were grouped into male and female rural community farmers. Thereafter simple random sampling was used to select 271 male 294 female farmers, and purposive sampling was used to identify 35 rural key informants, thereby bringing the total sample of 600 participants from the peri-urban rural communities. Therefore, the grant total sample size of 1250 participants voluntarily participated in this research.

Data collection methods, instruments and analysis
Questionnaires, interviews, focus group discussions and observation were used as the research methods and questionnaire guideline form, interview checklist, focus group discussion checklist and direct observation were used as the data gathering tools or instruments. These methods produced primary data where information was captured at the point where it was generated. Secondary data was collected through google scholar search of articles, journals, books and reports. The researcher did self-administer of the data collection instruments. Analysis started coding data according to the objectives of the study. The collected data was organised according to the themes that emerged from the response. This was an act of transforming data with the aim of extracting useful information and facilitating conclusions, and a research report was produced.

Results

Historical characteristics of participants
The whole targeted sample of 1250 of all participants were involved in the survey, male participants comprised 48% and females 52%, this applied both to the urban and rural community households. For the rural community, this scenario shows a higher proportion of female farmers engaged in agriculture and food security, as compared to male farmers. Participants within the age group 41- 50 years constituted the highest percentage ie 25%, whereas the lowest age group (below 30 years) constitutes the lowest proportion (10%).

Of all the rural communities households surveyed, 70% reported to have settled in 1964, 11% between 1980 and 1985, and 19% settled after 1985. The survey revealed that approximately 90% of participants settled on virgin land, whilst 10% settled on previously cleared land. This shows the majority of the participants command a greater understanding of the characteristics of the area.

The disposable management mechanism for the electronic waste
It was noted that 29% of the waste was electronic effluent released into water bodies, 29% of the waste was still kept in the backyard, whilst 22% of the waste was found a storeroom at homes and at workplaces. The research revealed methods of electronic waste disposal from homes and businesses as burning, backyard and storeroom storage, and throwing at landfill sites.

Table 1. Electronic waste disposal methods in the study area (%).

Participants	Landfill	Backyard storage	Open Burning	Storeroom	Effluent	Total
Household	3	6	2	69	20	100
Agriculture	15	16	11	14	44	100
Retail	23	13	10	17	37	100
Warehouse	18	26	12	12	32	100
Repair & construction	25	16	5	9	45	100
Manufacturing	17	13	2	24	44	100
NGOs	10	69	3	15	3	100
Government	2	71	3	19	6	100
Averages	14	29	6	22	29	100

Observed is electronic waste dumped at landfill, whilst some are thrown or released as mixed electronic water effluents in dams, ponds, weirs and streams adjacent to the industrial sites into Sakubva river.

Plate 1. Electronic waste at landfill and in the river.

Observed is stored electronic waste in the storeroom and at backyard, as organisations and

households struggled to manage the pilling electronic waste that had attained end of their useful life.

Plate 2. Electronic waste in storeroom and at backyard around Mutare industrial site.

Characteristics of the electronic waste and where are they stored

It was noted and grouped the major electronic waste as follows; home appliances, entertainment devices, office and medical equipment, communication devices and electronic utilises.

Table 2. Characteristics of electronic waste found in Mutare urban.

Characteristic of electronic waste	Popular electronic waste found	Comments
Home Appliances:	Microwaves, Home Entertainment Devices Electric cookers, Refrigerators, Heaters, Fans	Found in store rooms, and in door spare rooms
Home Entertainment Devices:	DVDs, Blu Ray Players, Stereos and radios, Televisions, Video Game Systems, Fax machines, Copiers, Printers	Taken to landfills dumping sites
Office and Medical Equipment	Copiers/Printers, IT Server Racks IT Servers, Cords and Cables, WiFi Dongles, Dialysis Machines, Imaging Equipment, Phone & PBX systems, Audio & Video, Equipment Network Hardware (i.e. servers, switches, hubs, etc.), Power Strips & Power Supplies, Uninterrupted Power Supplies (UPS Systems), Power Distribution Systems (PDU's), Autoclave, Defibrillator	Majority in the backyards and store rooms, whilst some are burnt
Communications and Information Technology Devices	Cell phones, Smartphones, Desktop Computers, Computer Monitors, Laptops, Circuit boards, Hard Drives	Being used as toys at homes, at workplace they are found in backyards
Electronic Utilities	Massage Chairs, Heating Pads, Remote Controls, Television Remotes, Electrical Cords, Lamps, Smart Lights, Night Lights, FitBits, Treadmills, Smart Watches, Heart Monitors, Diabetic Testing Equipment	Majority in the backyard and store rooms, whilst some are burnt

Impact of the electronic waste pollution on environment, agriculture activities and food security

It was noted that when large particles are released from burning, shredding or dismantling electronic waste, they quickly re-deposit to the ground and contaminate the soil as well, due to their size and weight. The rural key informants revealed that these pollutants can remain in the soil for a long period of time and can be harmful to microorganisms in the soil and plants.

Plate 3. Outflowing electronic waste effluent in Sakubva River from the industrial site.

It was noted that 88% of the participants agreed that if all electronic users dispose electronic waste improperly like letting the diluted chemical substance, all of those nasty components are leaching into the environment. The electronic pollutants will then infest soil and water, thus contaminating wildlife, livestock, and crops. These toxins are then passed around the food chain.

Plate 4. A crop field heavily affected after the use of electronic waste polluted water.

It was noted by both urban and rural key informants that soil pollution naturally contributes to air pollution by releasing volatile compounds into the atmosphere. They suggested that the more toxic compounds soil contains, the greater the air pollution it creates and that can lead to water pollution if toxic chemicals leach into groundwater or if contaminated runoff or sewage, which can contain dangerous heavy metals, reaches streams, lakes, or oceans. The research revealed that when applied repeatedly or in large amounts, these heavy metals can accumulate in soils to the point that it is unable to support plant life.

It was noted that downstream, the rural community fields and gardens were now useless as the soils are being affected by the use of electronic waste polluted water for irrigation. It was noted that 99% of the rural farmers were depending water from Sakubva River for on irrigation of gardens and field crops. It was noted that many of the environmental burdens more often borne by marginalized groups, such as minorities, women, and residents of rural communities downstream of Sakubva River.

Plate 5. Irrigated bean crop heavily affected by electronic waste pollutant.

It was noted that the loss of fertile soil makes land less productive for agriculture, creates new deserts, pollutes waterways and can alter how water flows through the landscape, potentially making flooding more common.

Plate 6. A injured pumpkin, wilting and diseased pumpkin plant in a nutrition garden.

The rural key informants indicated that that electronic waste pollution causes more damage to plants than all other pollutants combined as observed in the photo taken by the researcher beans crops and pumpkin leaves. Plates show classical symptoms of electronic chemical pollution injuries on beans crop and pumpkin leaves, these injuries will affects yield of several other major crops in the rural community gardens and crop fields.

Plate 7. A nutrition garden were cropping is still done year round using a well.

Only 1% had wells as source of water for watering their gardens. It was noted that majority are no longer farming year round as there is no enough, freshwater for farming during winter period.

Table 3. The environmental impact of the processing of different electronic waste component.

Electronic Waste Component	Process Used	Potential Environmental Hazard	Impact Ranking Percentages (%)
Cathode ray tubes (used in TVs, computer monitors, ATM, video cameras, and more)	Breaking and removal of yoke, then dumping	Lead, barium and other heavy metals leaching into the ground water and release of toxic phosphor	2 60 - 79%
Printed circuit board (image behind table - a thin plate on which chips and other electronic components are placed)	De-soldering and removal of computer chips; open burning and acid baths to remove metals after chips are removed.	Air emissions and discharge into rivers of glass dust, tin, lead, brominated dioxin, beryllium cadmium, and mercury	3 40 - 59%
Chips and other gold plated components	Chemical stripping using nitric and hydrochloric acid and burning of chips	PAHs, heavy metals, brominated flame retardants discharged directly into rivers acidifying fish and flora. Tin and lead contamination of surface and groundwater. Air emissions of brominated dioxins, heavy metals, and PAHs	1 80 - 100%
Plastics from printers, keyboards, monitors, etc.	Shredding and low temp melting to be reused	Emissions of brominated dioxins, heavy metals, and hydrocarbons	5 1 - 19%
Computer wires	Open burning and stripping to remove copper	PAHs released into air, water, and soil.	4 20 - 39%

Both key informants and the farmers noted that if electronic waste was managed in a sustainable way, toxic substances will be released into the environment. Cadmium, chromium, lead and other heavy metals, when exposed to the environment, leach into groundwater. Slowly, the metal builds up in the surface of contaminated soils, showing virtually no downward migration.

Plate 8. A citrus nursery under stress due to shortage of freshwater as wells are drying up.

The key informant interviews and focus group discussion revealed that there are human and environmental impact when electronic waste is disposed or dismantled. It was revealed that there are some social, environmental, economic and recovery cost attached on electronic pollution

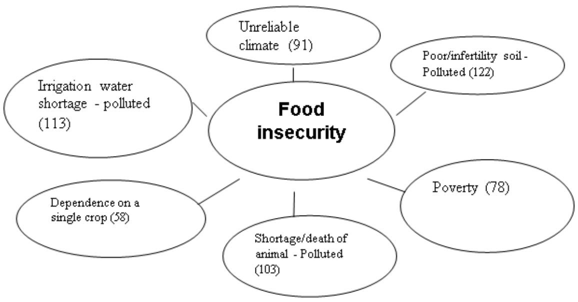

Fig. 1. Main causes of food insecurity in Mutare rural community.

Farmers highlighted the following factors as the root causes of food insecurity; irrigation water shortage as the water is contaminated and polluted with electronic waste. Unreliable climate, poor/infertility soil conditions, dependence on a single crop, shortage/death of animal due to consuming of electronic plastics or drinking polluted water, continuous ploughing leading into decline in availability of organic matter and poverty.

Strategies for electronic waste management to reduce adverse impacts on environment agriculture and food security

The participants came up with a business strategic management framework as a plan for electronic waste management in Mutare urban. However, before strategic management plan, it was noted that there are possible strategies that can be followed to help reduce the amount of electronic waste. The group discussion proposed the following:

- ➢ Be a good consumer. It was agreed that there was need to do some research when buying a new product. Make sure it's one that won't break easily or become damaged shortly after purchase. In other words, look for products likely to have a much longer lifespan so you won't need to replace it within a few years, or even months. It's known that this is a common practice in the electronics industry; to make products with shorter life spans so more money can be earned in the long run when they break or malfunction.
- ➢ Reuse as often as possible. It was noted that if they are parts and equipment that are still working, try repairing the electronic device before getting a new one. In addition, if the device is beyond the point of being repaired, then recycle it.
- ➢ Educate user on what is put into the electronics, as knowledge is power. It was agreed to doing some research about the raw materials being used to manufacture mobile phone or laptop as it helps understand how harmful those materials and toxins can be if they're tossed into a landfill. The more someone is educated the more can purchase items that will not be harmful to the environment.
- ➢ Look for an environmentally friendly label. For example, see if the products are labeled Energy Star, or have been certified by the Electronic Product Environmental Assessment Tool.
- ➢ Consider limiting the number of electronics someone or organisations own, that is if someone or organisation don't really need an extra gadget, look for devices that have multiple functions.
- ➢ Teach children about electronic waste, it was agreed that children are our future, and it helps if instilled within them at a young age a commit to electronic waste recycling.
- ➢ Recycle and recycle, no matter what someone or an orgahisation have, it is important to always dispose of electronic waste properly. That means recycling all used electronics, with the understanding that improperly disposing of electronic waste is becoming more and more hazardous, particularly since the volume of electronic waste has skyrocketed.
- ➢ Understand security issues. It was noted that all personal information remains stored on electronic devices even if deleted, so that's another reason not to throw it away.
- ➢ Maintain what someone or an orgnisation have. Small moves help keep what someone or an orgnisation have working longer. Clean someone or an orgnisation's computer often and don't overcharge the battery so as to improve battery's overall lifespan.

The participants noted that for sustainable electronic waste management to be achieved, the stakeholders are to be aware of how waste affects the three pillars of sustainable development.

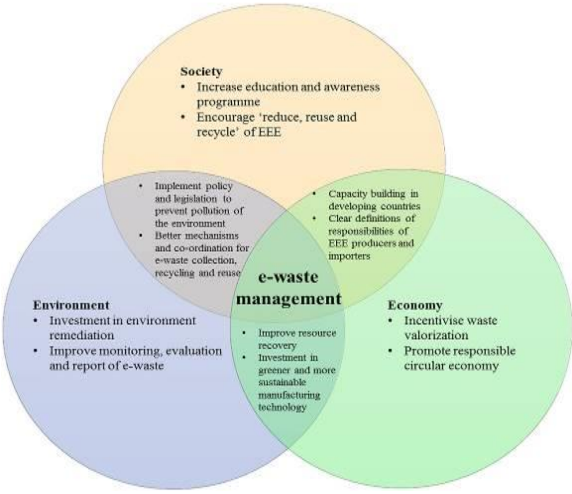

Fig. 2. A holistic approach to sustainable electronic waste management.

The research revealed that the sustainability concept represents a tie-in of the environment (ecosystems, pollution, natural resources, climate), economy (economic growth, jobs, living standards) and the society (food security, poverty eradication, equity promotion, gender equality, human rights, peace and justice) which are known as the pillars of sustainability.

It was noted that sustainable agriculture for food security is an essential catalyst for realization of sustainable development. Therefore as any entry point to strategic electronic waste management the participants agreed to a holistic approach as shown in the fig. below.

There after the participants developed a possible electronic waste management plan as show in the fig. for the Mutare community. It was proposed that there is need for market through linkage with international communities where the electronic waste could be sold from developing countries like Zimbabwe.

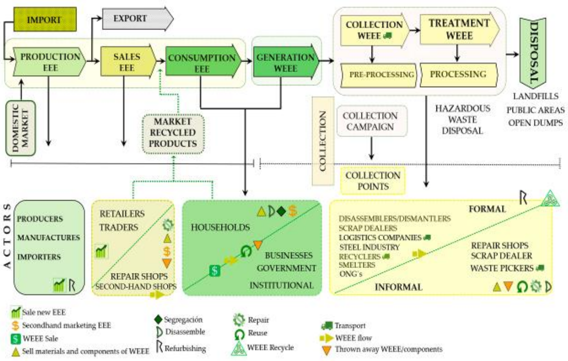

Fig. 3. Proposed electronic waste management plan for the Mutare community.

This was closely linked to the existing practices of electronic waste management in India. Unfortunate, it suffered from quite a few disadvantages like appropriate inventory, unhealthy conditions of informal recycling, inadequate legislation, poor awareness and reluctance on part of the corporate to address the critical issues involved.

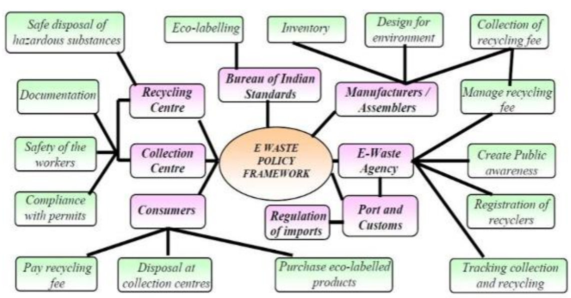

Fig. 4. The existing practices of electronic waste management in India.

Further, key informants heavily advocated for a need to develop a proposed draft of a national electronic waste strategy. Among the key informants, there were decision policy maker like the councillors, traditional leaders, members of the parliament and other government official from the environment, agriculture and business sector.

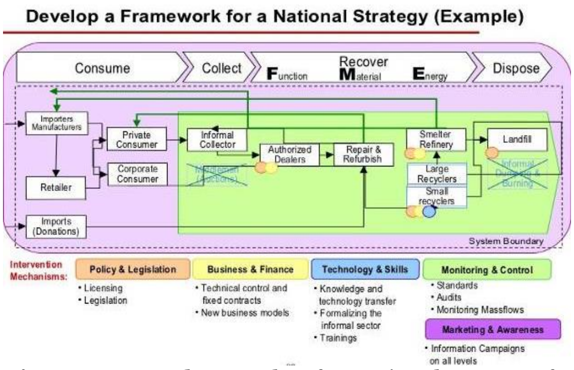

Fig. 5. Proposed example of a national strategy for electronic waste.

Nine seven percent (97%) of the participants agreed that sustainable agriculture allows for production of healthy foods without destroying the ability of future generations to do the same. The strategies that were proposed to attain food security in the affected area were; that farmers to avoid using the polluted water, but for gardening they should to start drill wells and boreholes, practice water harvesting and only utilise the rain water during summer from field crops. It was noted that the farmers are to practice the following sustainable agriculture practices; crop rotation, crop diversification and recycling (crop waste and animal manure). The rural community household farmers reported the following traditional soil fertility management practices and proposed to continue using them;

- Composting (including leaf litter)
- Animal / livestock manure
- Spreading mount soil
- Zero tillage
- Fallowing
- Leaving out particular indigenous trees in fields (which provide litter)
- Crop rotation and
- Intercropping.
- Liquid fertilizers/manure

The research revealed that the main issues posed by electronic waste were:

- High volumes are generated due to the rapid obsolescence of gadgets
- Toxic design as electronic waste is classified as hazardous waste
- Poor design and complexity of electronic equipment
- Labour issues, these include occupational exposures
- Financial incentives as there is not enough value in most electronic waste to cover the costs of managing it in a responsible way and,
- Lack of regulation as the country of Zimbabwe lack adequate regulations applying to this relatively new waste stream.

Discussion

The disposable management mechanism for the electronic waste

It was noted that mixed electronic and wastewater effluents are released to a wide variety of receiving environments around Mutare including dams, ponds, culverts, weir, streams and Sakubva river. Effluents released from electronic and wastewater systems do contain pollutants of concern since even advanced treatment systems are unable to remove all pollutants and chemicals.

It was revealed that as people try to dispose electronic waste, there was huge environmental pollution through burning, put in landfills or melted down as burnt toxins were persistent that created environmental, human health risks, agricultural land degradation and food insecurity. The emission of fumes, gases, and particulate matter into the air, the discharge of liquid waste into water and drainage systems, and the disposal of hazardous wastes contribute to environmental degradation (EMA, 2002. The processes of dismantling and disposing of electronic waste in developing countries led to a number of environmental impacts. The liquid and atmospheric gases released will end up in bodies of water, groundwater, soil, and air. Therefore in land and sea animals, both domesticated and wild, in crops eaten by both animals and human, and in drinking water (Frazzoli *et al.*, 2010).

Characteristics of the electronic waste and where are they stored

The key informants indicated that depending on the age and type of the discarded item, the chemical composition of electronic waste might vary. Most electronic waste are composed of a mixture of metals like Cu, Al and Fe (Wath *et al.*, 2011). The communities observed that when they used water from the boreholes and shallow well, there was some development of skin disease or there were foul smells, This is proof, that it is true, as the communities suspected, there are problems happening to their water sources (Diss, 2019). Electronic waste has a horrible effect on the environment and human health (Robinson, 2009). According to Mahipal *et al.* (2016), electronic wastes are considered dangerous, as certain components of some electronic products contain materials that are harmful, depending on their condition and density.

Mahipal *et al.* (2016) further indicated that the harmful content of these materials pose a threat to human health and environment. Its toxic emissions mixed with virgin soil and air and causing harmful effects to the entire biota either directly or indirectly. Mahipal *et al.* (2016) suggested that their direct impacts include release of acids, toxic compounds including heavy metals, carcinogenic chemicals and indirect effects such as bio magnification of heavy metals. Discarded computers, televisions. DVD. stereos, copiers, fax machines, electric lamps, cell phones, audio equipment and batteries if improperly disposed can leach lead and other substances into soil and groundwater (Mahipal *et al.*, 2016).

Impact of the electronic waste pollution on environment, agriculture activities and food security

Dharini *et al.* (2017) indicated that burning of electronic waste on an open landfill for obtaining gold and other precious metals produce fine particulate matter from the smoke produced and cause cardio-vascular and pulmonary ailments for children in that specific area.

Inappropriately managed waste can attract rodents and insects, which can harbour gastrointestinal parasites, yellow fever, worms, the plague and other conditions for humans, and exposure to hazardous wastes, particularly when they are burnt, can cause various other diseases including cancers (Ferronato and Vincenzo, 2019). Toxic waste materials can contaminate surface water, groundwater, soil, and air, which causes more problems for humans, other species, and ecosystems (Diaz *et al.*, 2006). Waste treatment and disposal produces significant greenhouse gas (GHG) emissions, notably methane, which are contributing significantly to global warming (EPA, 2003). As global warming and CO^2 emission increase, soil begins to become a larger carbon sink and will become increasingly volatile for our plant life (Kirschbaum, 2000). Waste management is a significant environmental justice issue as the effects of waste pollution heavily affect the rural communities downstream. It was revealed that this has led to climate change and adverse affected agricultural activities in the adjacent rural communities. They is major land degradation and river stream pollution, no nutrition gardens are still thriving downstream. This has negative impacted on food security in the rural communities downstream.

Soil pollution allows great quantities of nitrogen to escape through ammonia volatilization and denitrification and the decomposition of organic materials in soil can release sulfur dioxide and other sulfur compounds, causing acid rain (Mahipal *et al.*, 2016). Furthermore, the key informants revealed that acidic soils created by the deposition of acidic compounds, such as sulfur dioxide brought about by the burning of fossil fuels, produce an acidic environment that harms micro-organisms, which improve the soil structure by breaking down organic material and aiding in water flow. Soil pollution may alter plant metabolism and reduce crop yields and cause trees and plants that may absorb soil contaminants to pass them up the food chain. Soils polluted by acid rain have an impact on plants by disrupting the soil chemistry and reducing the plant's ability to take up nutrients and undergo photosynthesis. Soil pollution also causes the loss of soil and natural nutrients present in it, hindering plants ability to thrive in such soil, which would further result in soil erosion and disturbing the balance of flora and fauna residing in the soil (Mahipal *et al.*, 2016). While aluminum occurs naturally in the environment, soil pollution can mobilize inorganic forms, which are highly toxic to plants and can potentially leach into ground water, compounding their effects. Soil pollution increase the salinity of the soil making it unfit for vegetation, thus making it useless and barren. If some crops manage to grow under these conditions, they would be poisonous enough to cause serious health problems in people consuming them. The creation of toxic dust is another potential effect of soil pollution (Mahipal *et al.*, 2016). Furthermore, key informants indicated that contaminated soils with high levels of nitrogen and phosphorus can leach into waterways, causing algal blooms, resulting in the death of aquatic plants due to depleted dissolved oxygen. Finally, acidic deposition into the soil can hamper its ability to buffer changes in the soil pH, causing plants to die off due to inhospitable conditions. Dharini *et al.* (2017) concluded that from the observed soil test results they conducted it could be inferred that the soil samples subjected to harmful landfills are infertile and are made unfit for vegetation permanently. This is because the lead content depletes the soil of its natural nutrients and makes it sterile. Flora and fauna of the area near the landfill gets affected since the landfill releases particulate matter casing air pollution (Dharini *et al.*, 2017).

Strategies for electronic waste management to reduce adverse impacts on environment agriculture and food security

The participants came up with a business strategic management framework as a plan for electronic waste management in Mutare urban. Mahipal *et al.* (2016) supported this idea and indicated that the proper electronic waste management will help efficient sourcing and collection right up to extraction and disposal of material, ensure that this huge pile up of electronic waste will turn into lucrative products and business opportunity. As the research came up with the strategy for management of the electronic waste, it was noted that many of the environmental burdens more often borne by marginalized groups, such as minorities, women, and residents of rural communities downstream of Sakubva river. Not in my backyard (NIMBY) is the opposition of residents to a proposal for a new development because it is close to them (Wolsink, 1994). However, the need for establishment of waste treatment and disposal facilities was said to increasing worldwide. There is now a growing market in the transboundary movement of waste, and although most waste that flows between countries goes between developed nations. A significant amount of waste is moved from developed to developing nations (Ray, 2008).

The economic costs of managing waste are high, and are often paid for by municipal governments (Economist, 2009); money can often be saved with more efficiently designed collection routes, modifying vehicles, and with public education. Environmental policies such as pay as you throw can reduce the cost of management and reduce waste quantities. Waste recovery (that is, recycling, reuse) can curb economic costs because it avoids extracting raw materials and often cuts transportation costs. These policies can significantly alter or reduce waste in a particular system, but other negative economic effects come with the disease, poverty, exploitation, and abuse of its workers (Wilson *et al*., 2006). However, according to Dharini *et al.* (2017), generally treating and processing electronic waste is an expensive task and space becomes a huge challenge as the problem is convoluted by the toxicity of the waste that is being handled by workers and dumped unsafely in municipal yards Gahukar. (2009) concluded that the unsustainable agriculture practices have affected food availability, accessibility, utilization and stability in the rural communities. Therefore the participants suggested the following ssustainable agriculture practices for the rural community of Mutare.

- Rotating crops and embracing diversity
- Planting cover crops
- Reducing or eliminating tillage
- Applying integrated pest management (IPM)
- Integrating livestock and crops
- Adopting agroforestry practices
- Managing whole systems and landscapes.

The research revealed the main issues posed by electronic waste, it was interesting to noted that these issues match with what other authors suggested or highlighted as well. Smith *et al.* (2006) indicated poor design and complexity in that electronic waste imposes many challenges on the recycling industry as it contains many different materials that are mixed, bolted, screwed, snapped, glued or soldered together. Toxic materials are attached to non-toxic materials, which makes separation of materials for reclamation difficult. Hence, responsible recycling requires intensive labour and/or sophisticated and costly technologies that safely separate materials (BAN, 2011).

BAN, (2011) also indicated the issue of high volumes in that high volumes are generated due to the rapid obsolescence of gadgets combined with the high demand for new technology. Toxic design, electronic waste is classified as hazardous waste (Tsydenova & Bengtsson, 2011) having adverse health and environmental implications. Approximately 40 per cent of the heavy metals found in landfills comes from electronic waste (Montrose, 2011). The labour issues, these include occupational exposures, informal sector domination causing health and environmental problems, lack of labour standards and rights. Widmer *et al.* (2005) highlighted that financial incentives was any issue as in general, there is not enough value in most electronic waste to cover the costs of managing it in a responsible way. However, in line with EPR policies, new opportunities can be realized with the rise in the price of many of the materials in electronics, such as gold and copper. Furthermore, with rising electronic waste quantities, formal recyclers are increasingly entering the electronic waste recycling sector (Raghupathy *et al*., 2010).

Lack of regulation, BAN (2011) reviewed that many nations either lack adequate regulations applying to this relatively new waste stream, or lack effective enforcement of new electronic waste regulations.

Conclusion

In essence, there was need for a sustainable solution as electronic waste was seen pilled in backyards and in storerooms. There has been no sustainable waste management strategies presented up until the one developed during the research period. The electronic waste remains a human health danger and environment pollutant polluting the land, soil, water, and air. Food security as a state where the availability, accessibility, utilization and stability of food is attained has been heavily affected as water for gardening and field crop irrigation is polluted.

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