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Effect of linear view approach of weed management in agro-ecosystem: A review

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Weeds are considered a pest that is detrimental to human interest. Weeds compete with cultivated and desirable plants for space, soil nutrient, and sunlight and soil moisture thereby reducing crop productivity. Weeds also serve as a host for pests and pathogens that cause plant diseases. Weeds typically produce large numbers of seeds, assisting their spread, and rapidly invade disturbed sites. Seeds spread into natural and disturbed environments, via wind, waterways, people, vehicles, machinery, birds and other animals. To prevent the effect of weeds on crop productivity, farmers mostly use a linear approach for weed management. The linear view approach aims at eradicating weeds without concern about the environment. This paper reviews the effects of the linear view approach of weed management in the agro-ecosystem. A review using forty-one articles reveals that herbicides application, bush burning and soil tillage are the most often used linear view approach for controlling weeds in the farm ecosystem. The paper highlights the contribution of these weed control methods to climate change through loss of biodiversity, pollution of water bodies, soil degradation, deterioration of fruit quality and release of carbon dioxide to the atmosphere.

Key words: Herbicides, biodiversity, bush burning, soil tillage.

INTRODUCTION

A weed is any plant growing in the wrong place, that is, undesirable areas and conflicts with human interest. Moreover, good for nothing plants are also termed as weeds (Holzner, 1982). Ecologists view weeds as colonizers. According to Holzner (1982) and Hahn (2019), weed types can be categorized into various classes which include; agrestal, ruderals, grassland weeds, water weeds, forestry weeds, and environmental weeds. Agrestals are weeds of farmed or arable land which includes root crops, cereals, orchards, and even plantations. Ruderals are plants occurring on debris such as the earth heaps. Grassland weeds are also referred to

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Table 1. The life cycle of weeds and their common examples.

Lifecycle of weeds	Definition	Examples	Sources
Annual	Weeds that complete their lifecycle within one growing season	Redroot pigweed(*Amaranthus retroflexus*)	Knezevic et al. (1994); Pacifico et al. (2008)
Biennial	Weeds that complete their lifecycle in over two growing season	Musk thistle(*Carduus nutans*)	Smith and Kok (1984)
Perennial	Weeds that continue to regrow over several seasons to many seasons, that is, they live more than a single season.	Couch grass (*Elytrigia repens*)	Glinwood et al. (2003)

as pasture weeds and are mainly perennial. Water weeds hinder human activities especially in slowing down the flow of irrigation water in waterways. Forestry weeds are the forest plants that hinder the growth of young trees. Lastly, environmental weeds are the species that colonize natural vegetation and suppress the indigenous species to a certain extend. Weeds can be annual, perennial, or biennial depending on their lifecycle (Table 1).

In the arable lands, both the annual and perennial weeds have various characteristics attributed to them. Both annual and perennial crops experience weed as a common problem (Karim et al., 2004). However, annual crops are not only attacked by annual weeds but also by perennial weeds. Some of the worst weeds in annual crops are perennial plants whereas annual weed species have difficulties in thriving among perennial crops with dense canopies (Håkansson, 1982). Biennial weeds are also found in the arable lands since they take over two seasons to complete their cycle. Weeds are detrimental while in the field since they compete for water, nutrients, space, and sunlight with the crops; (Benayas et al., 2002). They have been acting as hosts to harmful pests and diseases which have led to a reduction in the expected crop yields. As a result of this, weed control has become a major area of concern in the agricultural sector which has led them to use any means available to eradicate them. Linear view approach of weed management aims at eradicating weeds without concern about the environment Most of these methods used affect the agro-ecosystem negatively and they include the use of herbicides, tillage, and bush burning (slushing and burning).

The continuous use of chemical weed control methods contaminates the soil since the chemical residues accumulate in the soil containing heavy metals such as lead (Pb), zinc (Zn), and copper (Cu) (Rose et al., 2016; Apori et al., 2018). This affects the soil physicochemical properties as well as the distribution of micro-organisms in the soil. Once it rains, the chemical residues are carried by the water runoffs or washed into water reservoirs hence contaminating the surface water, groundwater, and the underground water. Continuous tillage which is the main way of weed eradication leads to soil compaction which enhances hardpan development (Welch et al., 2016). Moreover, bush burning also releases gases that contribute to climate change into the atmosphere. The opposite of linear view approach of weed management is the wide view approach of weed management which ensures that the environment is taken care of during weed management so as to enhance biodiversity sustainability. Therefore, this article seeks to review the effect of herbicides application, tillage practices, and bush burning in the agroecosystem.

LINEAR VIEW APPROACH OF WEED MANAGEMENT

Herbicides application

Herbicides are agrochemicals that belong to the class of pesticides used to control unwanted plants. They are categorized based on the time of application, mode of application, and biological effect (Table 2). Under the time of application, they can be categorized into pre-plant, pre-emergent, and post-emergent herbicides (Willoughby et al., 2003). Pre-plant herbicides are applied before the crop is planted/transplanted into the main field such as glyphosate (Figure 1) which kills weeds before planting (Duke and Powles, 2008; Bradberry et al., 2004).

On a different note, the pre-plant herbicide can be into the soil especially in rice-growing fields (Karim et al., 2004). The pre-emergent ones target the grassy weeds and the broad-leaf weeds and they are applied to the soil surface such as butachlor (Yu et al., 2003) while the post-emergent are selective (target specific weed species) and non-selective (broad-spectrum) in nature (Kaeser and Stewart, 2010; Dear et al., 2006). An example of the post-emergent herbicide is propanil (Villarroel et al., 2003).

Under the mode of application, herbicides can either be foliar applied or soil applied. Foliar applied herbicides are directly sprayed on the leaves such as 2, 4-dichlorophenoxyacetic acid (Garabrant and Philbert, 2002). On the other hand, soil-applied herbicides are sprayed on the soil surface targeting germinating weeds. Under the biological effect category, herbicides can be grouped according to the mode of action, and according to selectivity (selective or non-selective). The mode of action involves contact herbicides and systemic herbicides. The contact herbicides are applied to the leaves and kill plant tissues, e.g. paraquat (Smith et al., 1976). The systemic herbicides transit within the plant, e.g. bispyribac sodium (Toni et al., 2010). Different concentrations of herbicides affect the environment differently. According to Gaupp-Berghausen et al. (2015), glyphosate-based herbicides reduce the activity and the reproduction of earthworms and lead to the rising of soil nutrient concentrations. Yusof et al. (2014) found out that glyphosate herbicide reduced the hatching and the survival percentage of Java medaka (*Oryzias javanicus*) fish as its concentration increased.

Tillage

Tillage is an important weed control tool in organic farming. According to Kuipers (1970), weed control is the only sure effect of tillage on crop production. Tillage has various systems such as reduced/minimum tillage and zero tillage which substitute herbicides for tillage (Kladivko, 2001; Lee and Stewart, 1983; Rusu, 2014). In most cases, tillage for weed control depends on the prevailing weather conditions for it to be successful. Mixtures of weed species are affected by the presence or absence of tillage operations. Zero-tillage systems experience challenges from perennial weeds and weeds that are dispersed by wind (Derksen et al., 1996). In conventional tillage system, the soil storage capacity of plant biomass is reduced which results to reduced moisture and high temperature hence low microbial activity (Aziz et al., 2013). Moreover, weed seeds are buried in the soil and end up germinating due to the favorable conditions (Forcella and Lindstrom, 1988).

Bush burning

Bush burning is the act of setting weeds and grasses in uncultivated farmlands on fire. Farmers can also burn the crop residues left after harvesting in preparation for the next planting season. This mainly takes place during the dry periods. Bush burning has negative effects on humankind's health and also pollutes the environment (Table 3). It releases gases such as carbon monoxide, hydrogen sulfide, nitrogen oxides, sulphur oxides, and even ozone (Izah et al., 2017). Uncontrolled bush burning is harmful to the agro-ecosystem as it destroys gardens, livestock, crops, soil micro-organisms, and soil physicochemical properties. Some farmers within the tropics slush the unwanted plants during land preparation then set them on fire.

Effect of linear view approach of weed management in agro-ecosystem

Effect of herbicides concentration on soil quality indicators and water quality

In the past years, the contamination of soils by inorganic toxins due to the application of herbicides and other chemicals in agricultural production has been on the rise (Zhang et al., 2013). The continued use of herbicides in weed management has affected soil physiochemical and biological properties. The moisture content in soils that have herbicides applied in them reduces drastically within a short period. Moreover, herbicides remove essential soil minerals and make them unavailable for uptake by plants (Sebiomo et al., 2012). This results in the alteration of soil chemical properties which ends up affecting plant growth and the potential yield. In the case of round-up which is made up of glyphosate, it increases the soil concentrations of both nitrate and phosphate which possess a risk of leaching (Gaupp-Berghausen et al., 2015). Herbicide concentration takes advantage of the cation exchange capacity (CEC) of the soil and bind to the soil colloids. This concentration can be maintained at toxic levels. These toxic levels leave behind chemical residues which could dissolve into the available groundwater since the herbicides bind with the soil colloids and are less available to crops (Johnson and Colmer, 1955).

Soil biodiversity brings out the variability among living organisms such as fungi, bacteria, and protozoa in the soil. The application of both pre-plant, pre-emergent, and post-emergent herbicides in crop production impacts soil biodiversity. Most studies point out that herbicide application impacts are only minor but according to Rose et al. (2016), herbicides consistently alter soil functions. Application of glyphosate and atrazine herbicides interferes with the earthworm ecology in soils. Moreover, sulfonylurea herbicides inhibit the soil nitrogen cycle (including biological nitrogen fixation) in low organic matter soils (Rose et al., 2016). Moreover, the concentration of the increasing herbicide harms the soil microorganism population (Pochron et al., 2019). According to Johnson and Colmer (1955), the microorganism population is reduced as a result of the herbicide concentration in the soil. In their study which involved different treatments, the population of bacteria counted in the soil drastically reduced after the herbicides application. In an experiment, Gaupp-Berghausen et al. (2015) established that glyphosate-based herbicide reduced the casting activity of vertically burrowing earthworms *(Lumbricus terrestris*) and also reduced the production of soil-dwelling earthworms.

Herbicide application affects both the surface and the

Table 2. Examples of herbicides, time and mode of application and their mode of action.

Herbicide name	Time and mode of application	Mode of action	Sources
Glyphosate	Applied before the planting time through spraying the targeted weeds.	Non-selective; absorbed through plant leaves and transported to other plant parts	Busse et al. (2001); Duke (2018)
Simazine	Applied prior to weed germination by spraying into the soil	Absorbed via the roots	Grover (1966)) Ertan et al. (2016)
Bentazone	Applied through spraying in rice, soyabeans, corn, peanuts and lima beans farms after germination of the weeds	Post-emergent for control of broad-leaved weeds	Carrizosa et al. (2000); Wang et al. (2015)
S-Metolachlor	Pre-plant surface application in 30days before planting or pre-plant incorporation during planting can be used.	Broad-spectrum for annual grasses	Liu and Xiong, 2009; Stara et al. (2019)
Chlorsufuron	Applied either before planting or after planting by spraying.	Both pre and post-emergent characterized by some soil residual activity	Thirunarayanan et al. (1985)
Iodosulfuron methyl-sodium	Applied after emergence via spraying.	Post-emergent herbicide used for some grasses and broadleaf weeds.	Drolc and Pintar (2011)
Paraquat	Applied during planting preparation by spraying.	Non selective contact herbicide	Grillo et al. (2014)
Imazamox	Applied after emergence via sparying.	Post emergent herbicide	Safarpour et al. (2004)
Linuron	Applied during land preparation so as to kill the weeds via spraying.	Nonselective herbicide for grasses and broadleaf weeds; inhibits photosynthesis	Van den Brink et al. (1997)
\Imazapic	Can either be applied before planting or after planting via spraying	Selective pre and post-emergent herbicide for some grasses, perennial grasses, and some broadleaf weeds	Shinn and Thill, 2004
Glufosinate ammonium	Applied before planting to manage glyphosate resistant-weeds	Broad-spectrum contact herbicide	Carpenter et al. (2010); (Takano (2019)
2, 4-D	At the time of treatment, weeds should be small and actively growing. Application is done through ground or aerial spraying	Broadleaf herbicide	Song (2014)
Aminopyralid	Applied after the emergence of weeds via spraying.	Broadleaf herbicide	Bukun et al. (2010); Seefeldt et al. (2013)

Source: Author's findings.

groundwater. The application of herbicides compromises with the water quality since they are water-soluble and can leach into the groundwater and the surface water (Thurman et al., 1991). The use of herbicides has led to reduced water quality which is one of the existing environmental problems that the world is facing today (Misra et al., 1996). When it rains, the herbicides dissolve into the water and the runoff water washes them into water bodies like lakes, rivers, and groundwater aquifers. Water inhabiting animals like fish have had to tolerate weed killers from agronomic activities that have been washed into the water bodies (Mullison, 1970).

Table 3. Key findings of bush burning in the environment.

Source	Key findings
Birnin-Yaur et al. (2008)	It affects different weed species differently. It leads to termination of grass weed species while increasing the prevalence of broadleaved weed species
Bebawi and Campbell (2002)	It reduces the weed seed bank in various soils. However, the deeper the weed seeds in the soil the less the impact of the fire temperatures which leaves them viable for germination
Inyang and Esoh (2014)	It is harmful to human beings and the environment as it involves production of air pollutants (Carbon monoxide, hydrogen sulphide, nitrogen oxides, sulphur oxides, ozone)
Izah et al. (2017)	Bush burning reduces the soil microbial population and diversity
Ohwoghere-Asuma (2012)	Bush burning reduces the value of carbon, organic matter, nitrogen and pH.
Vågen et al. (2005)	Bush burning reduces soil organic carbon on the upper soil profile.
Bagoora (1988)	Bush burning increases soil erosion risk in highland areas.

Herbicides concentration on fruit quality

Herbicide application in fruit production affects the yield and fruit quality. According to Mohammed and Ali (1986), the yield of tomato fruit reduced significantly when herbicides were used for weed control as compared to hand cultivation. Moreover, the level of ascorbic acid in the tomato fruits significantly increased as compared to the untreated ones. Some herbicides like treflan reduce the general fruit acidity. However, according to Maia et al. (2012), the use of herbicides such as diuron fluazifop-p-butyl and atrazine+ S-metolachlor does not affect the quality of some fruits like pineapple.

Effect of tillage on soil compaction, soil infiltration, and porosity

Soil compaction is the soil structure degradation (SSD) which is one of the most popular and harmful forms of land degradation in agriculture (McGarry, 2003). Compacted soils have low porosity, low air as well as low water permeability. Since tillage (conventional, zero and reduced) is the most used means of weed control in organic farming, it could contribute to soil compaction that affects soil water availability, nutrient availability and could contribute to soil erosion (Badalíková, 2010). According to Badalíková (2010), conventional tillage result in higher bulk density which connotes reduced water infiltration resulting in lower porosity. The lower range of tilling the soil favors reduced bulk density which increases water infiltration. Tillage also affects soil infiltration as some tillage methods interfere with surface connected pores and prevent the accumulation of soil organic matter. This also ends up reducing the porosity. Reduced tillage improves soil infiltration and also reduces surface runoff (Mupangwa et al., 2013)

Effect of bush burning in the environment

Bush burning is used as a means of weed control especially after harvesting in preparation for the next season. In most cases, slashing is done before the burning (Akobundu, 1979). Weeds, grasses and crop residues are set on fire and end up releasing various gases which pollute the atmosphere. Such gases include carbon monoxide, carbondioxide, hydrogen sulphide, nitrogen oxides, sulphur oxides and even ozone. These gases contribute to the greenhouse gas effect, acid rain, and ozone layer depletion which intensifies climate change. The acidic rain that is received alters the soil pH. On the other hand, bush burning causes a decrease in composition and abundance of biodiversity (Izah et al., 2017; Jamala et al., 2012; Birnin-Yauri et al., 2008). According to Schoch and Binkley (1986), bush burning reduces nutrient pool sizes through ash transport, leaching and erosion. At the same time, bush burning improves the availability of nutrients since fire converts the nutrients held in soil surfaces and plant debris to more available forms. According to Hough (1981), the concentration of some nutrients such as calcium, potassium and magnesium ions can be unaltered by bush burning while nitrogen and sulphur depreciate. The intensity of the fire in bush burning determines the kind of effects imposed on soil microbes. Moreover, there is decreased microbe abundance as a result of bush burning. According to Poth et al. (1995), the level of activity by microbes is higher than that of the microbial community preceding bush burning fire.

Contribution of linear view approach of weed management to greenhouse gases emissions

The linear view approach of weed management practices

Figure 1. A field where glyphosate herbicide has been used for weed control in central Uganda. (Source: Authors)

contributes to greenhouses gases either positively or negatively. The effects of herbicides on greenhouse gas emissions remain unclear (Jiang et al., 2015). According to Brookes et al. (2017), some herbicides such as glyphosate and butachlor reduce N_2O and CO_2 but do not affect CH_4. Herbicide application reduces the use of fuel by machines that are used in conventional tillage which reduces greenhouse gas emission (Gianessi, 2013). Zero tillage reduces greenhouse gas emissions due to the curtailing of the use of heavy machinery (Maraseni and Cockfield, 2011). According to Mangalassery et al. (2014), conventional tillage contributes to the change of state of CO_2 and CH_4 gases while it has no impact on N_2O. Moreover, according to Lognoul et al. (2017), N_2O and CO_2 emissions are higher in reduced tillage ascompared to conventional tillage. Conventional tillage distributes crop residues within the soil profile raising the organic C and N content. Straw returning enhances carbon sequestration. Burning biomass releases CO_2, N_20, CH_4, and other greenhouse gases into the atmosphere and burning of crop residues that store carbon releases CO_2 into the atmosphere which is a greenhouse gas (Guoliang et al., 2008).

Knowledge gap

Fruit quality is affected differently by various herbicides applications as they decrease fruit yield and rise in ascorbic acid while as per Maia et al. (2012) concluded that fruit yield and ascorbic acid remained constant after herbicide application. There is a need for further research to find out the actual effects on growth, yield, and quality in other fruits since the effects seem to differ in each fruit. Nutrients such as calcium, potassium and magnesium ions can be unaltered by bush burning while nitrogen and sulphur depreciate. However, to what extent will bush burning affects potassium, calcium, magnesium, and nitrogen dynamics in different soils.

Conclusion

The linear view approach of weed management remains

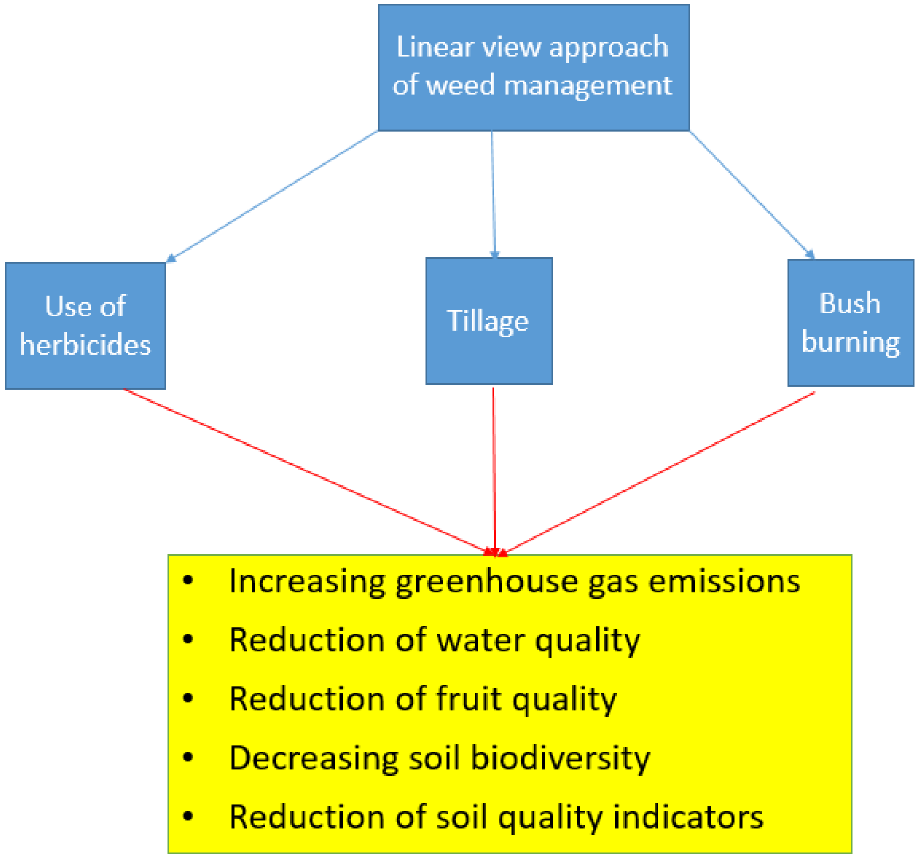

Figure 2. Summary of the linear view approach of weed management and its impact in the environment.

a key area affecting the agroecosystem (Figure 2).

Application of herbicides, tillage and bush burning affect the physicochemical and biological properties of soil resulting in low soil fertility. It also pollutes surface and underground water quality. Furthermore, it contributes to greenhouse gases emission. There is a need to carry out awareness among farmers and policymakers as it relates to proper ways of herbicide handling, proper tillage practices and controlled bush burning to avoid their detrimental effects on the environment. There is a need for emphasis on the adoption of WIDE VIEW APPROACH of weed management to enhance sustainable agriculture and meet the sustainable development goals.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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REFERENCES

Akobundu IO (1979). Weed control in Nigeria. Pans 25(3):287-298.
Apori OS, Hanyabui E, Asiamah YJ (2018). Remediation technology for copper contaminated soil: A review. Asian Soil Research Journal 8:1-7.
Aziz I, Mahmood T, Islam KR. (2013). Effect of long term no-till and conventional tillage practices on soil quality. Soil and Tillage Research 131:28-35.
Badalíková B. (2010). Influence of soil tillage on soil compaction. InSoil Engineering (pp. 19-30). Springer, Berlin, Heidelberg.
Bebawi FF, Campbell SD (2002) Effects of fire on germination and viability of bellyache bush (Jatropha gossypiifolia) seeds. Australian Journal of Experimental Agriculture 42(8):1063-1069.
Bagoora FD (1988) Soil erosion and mass wasting risk in the highland area of Uganda. Mountain research and development 1:173-182.
Benayas JM, López-Pintor A, García C, de la Cámara N, Strasser R, Sal AG (2002). Early establishment of planted Retama sphaerocarpa seedlings under different levels of light, water and weed competition. Plant Ecology 159(2):201-209.
Birnin-Yauri YA, Aliero BL (2008) Implications of bush burning on weed species diversity, population density and organic matter content of the soil in Birnin-Yauri, Kebbi, Nigeria. Journal of Applied Sciences and Environmental Management 12(1).
Bradberry SM, Proudfoot AT, Vale JA (2004). Poisoning due to

chlorophenoxy herbicides. Toxicological Reviews 23(2):65-73.
Brookes G, Taheripour F, Tyner WE (2017). The contribution of glyphosate to agriculture and potential impact of restrictions on use at the global level. GM Crops and Food 8(4):216-28.
Bukun B, Shaner DL, Nissen SJ, Westra P, Brunk G. (2010) Comparison of the interactions of aminopyralid vs. clopyralid with soil. Weed Science 58(4):473-477.
Busse MD, Ratcliff AW, Shestak CJ (2001). Powers RF. Glyphosate toxicity and the effects of long-term vegetation control on soil microbial communities. Soil Biology and Biochemistry 33(12-13):1777-89.
Carpenter D, Boutin C. Sublethal (2010). Effects of the herbicide glufosinate ammonium on crops and wild plants: short-term effects compared to vegetative recovery and plant reproduction. Ecotoxicology 19(7):1322-1336.
Carrizosa MJ, Calderon MJ, Hermosın MC, Cornejo J (2000). Organosmectites as sorbent and carrier of the herbicide bentazone. Science of the Total Environment 247(2-3):285-293.
Dear BS, Sandral GA, Wilson BC (2006). Tolerance of perennial pasture grass seedlings to pre-and post-emergent grass herbicides. Australian Journal of Experimental Agriculture 46(5):637-644.
Derksen DA, Blackshaw RE, Boyetchko SM (1996). Sustainability, conservation tillage and weeds in Canada. Canadian Journal of Plant Science 76(4):651-659.
Drolc A, Pintar A (2011). Measurement uncertainty evaluation and in-house method validation of the herbicide iodosulfuron-methyl-sodium in water samples by using HPLC analysis. Accreditation and Quality Assurance 16(1):21-29.
Duke SO, Powles SB (2008). Glyphosate: a once-in-a-century herbicide. Pest Management Science: formerly Pesticide Science 64(4):319-25.
Duke SO (2018) The history and current status of glyphosate. Pest management science 74(5):1027-34.
Ertan B, Eren T, Ermiş İ, Saral H, Atar N, Yola ML (2016) Sensitive analysis of simazine based on platinum nanoparticles on polyoxometalate/multi-walled carbon nanotubes. Journal of Colloid and Interface Science 470:14-21.
Forcella F, Lindstrom MJ. (1988) Weed seed populations in ridge and conventional tillage. Weed Science 1:500-5003.
Garabrant DH, Philbert MA. (2002) Review of 2, 4-dichlorophenoxyacetic acid (2, 4-D) epidemiology and toxicology. Critical Reviews in Toxicology 32(4):233-257.
Gaupp-Berghausen M, Hofer M, Rewald B, Zaller JG (2015) Glyphosate-based herbicides reduce the activity and reproduction of earthworms and lead to increased soil nutrient concentrations. Scientific Reports 5:12886.
Gianessi LP (2013). The increasing importance of herbicides in worldwide crop production. Pest Management Science 69(10):1099-105.
Glinwood R, Pettersson J, Ahmed E, Ninkovic V, Birkett M, Pickett J. (2003). Change in acceptability of barley plants to aphids after exposure to allelochemicals from couch-grass (Elytrigia repens). Journal of Chemical Ecology 29(2):261-274.
Grillo R, Pereira AE, Nishisaka CS, De Lima R, Oehlke K, Greiner R, Fraceto LF (2014). Chitosan/tripolyphosphate nanoparticles loaded with paraquat herbicide: an environmentally safer alternative for weed control. Journal of Hazardous Materials 278:163-171.
Grover R (1966). Influence of organic matter, texture, and available water on the toxicity of simazine in soil. Weeds 14(2):148-151.
Guoliang CA, Zhang X, Sunling GO, Zheng F (2008). Investigation on emission factors of particulate matter and gaseous pollutants from crop residue burning. Journal of Environmental Sciences 20(1):50-55.
Hahn D, Roosjen P, Nijp J, Leinauer B (2019) Object based image analysis of high resolution multi-spectral imagery for classifying and quantifying weeds in turfgrass areas. InASA, CSSA and SSSA International Annual Meetings Nov 11. ASA-CSSA-SSSA.
Håkansson S (1982). Multiplication, growth and persistence of perennial weeds. In Biology and ecology of weeds. Springer, Dordrecht pp. 123-135
Holzner W (1982). Concepts, categories and characteristics of weeds. In Biology and ecology of weeds. Springer, Dordrecht pp. 3-20
Inyang MP, Esohe KP (2014) Deforestations, environmental sustainability and health implications in Nigeria: A review. International Journal of Science, Environment and Technology 3(2):502-517.
Hough WA (1981). Impact of prescribed fire on understory and forest floor nutrients (Vol. 303). US Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.
Izah SC, Angaye TC, Aigberua AO, Nduka JO (2017) Uncontrolled bush burning in the Niger Delta region of Nigeria: potential causes and impacts on biodiversity. International Journal of Molecular Ecology and Conservation 15:7.
Jamala GY, Boni PG, Abraham P, Teru CP (2012). Evaluation of environmental and vulnerability impact of bush burning in southern guinea savanna of Adamawa state, Nigeria.
Jiang J, Chen L, Sun Q, Sang M, Huang Y (2015) Application of herbicides is likely to reduce greenhouse gas (N2O and CH4) emissions from rice–wheat cropping systems. Atmospheric Environment 107:62-69.
Johnson EJ, Colmer AR (1955). The Effect of Herbicides on Soil Microorganisms: I. The Effect of 2, 4-Dichlorophenoxyacetic Acid on Some Phases of the Nitrogen Metabolism of Bacillus cereus. Applied Microbiology 3(2):123.
Kaeser MJ, Kirkman LK (2010). The effects of pre-and post-emergent herbicides on non-target native plant species of the longleaf pine ecosystem. The Journal of the Torrey Botanical Society 137(4):420-430.
Karim RS, Man AB, Sahid IB (2004) Weed problems and their management in rice fields of Malaysia: an overview. Weed Biology and Management 4(4):177-186.
Kladivko EJ. (2001) Tillage systems and soil ecology. Soil and Tillage Research 61(1-2):61-76.
Knezevic SZ, Weise SF, Swanton CJ (1994). Interference of redroot pigweed (*Amaranthus retroflexus*) in corn (*Zea mays*). Weed Science pp. 568-573.
Kuipers H (970). Historical notes on the zero-tillage concept. NJAS wageningen journal of life sciences 18(4):219-224.
Lee LK, Stewart WH (1983) Landownership and the adoption of minimum tillage. American Journal of Agricultural Economics 65(2):256-264.
Liu H, Xiong M (2009) Comparative toxicity of racemic metolachlor and S-metolachlor to Chlorella pyrenoidosa. Aquatic Toxicology 93(2-3):100-106.
Lognoul M, Theodorakopoulos N, Hiel MP, Regaert D, Broux F, Heinesch B, Bodson B, Vandenbol M, Aubinet M. (2017). Impact of tillage on greenhouse gas emissions by an agricultural crop and dynamics of N2O fluxes: Insights from automated closed chamber measurements. Soil and Tillage Research 167:80-89.
Maia LC, Maia VM, Aspiazú I, Pegoraro RF (2012).Growth, production and quality of pineapple in response to herbicide use. Revista Brasileira de Fruticultura 34(3):799-805.
Mangalassery S, Sjögersten S, Sparkes DL, Sturrock CJ, Craigon J, Mooney SJ (2014). To what extent can zero tillage lead to a reduction in greenhouse gas emissions from temperate soils?. Scientific reports 4(1):1-8.
Maraseni TN, Cockfield G (2011). Does the adoption of zero tillage reduce greenhouse gas emissions? An assessment for the grains industry in Australia. Agricultural Systems 104(6):451-458.
McGarry D (2003). Tillage and soil compaction. In Conservation agriculture. Springer, Dordrecht pp. 307-316.
Misra AK, Baker JL, Mickelson SK, Shang H (1996). Contributing area and concentration effects on herbicide removal by vegetative buffer strips. Transactions of the ASAE 39(6):2105-2111.
Mohammed AI, Ali AY (1984). Effect of herbicides on yield and fruit quality of tomato. In Symposium on Tomato Production on Arid Land 190:191-196.
Mullison WR (1970). Effects of herbicides on water and its inhabitants. Weed Science 1:738-750.
Mupangwa W, Twomlow S, Walker S (2013). Cumulative effects of reduced tillage and mulching on soil properties under semi-arid conditions. Journal of Arid Environments 91:45-52.
Ohwoghere Asuma O (2012). Impact of degradation processes on physical and chemical properties of soils in Delta State of the Niger

Delta. Journal of Geology and Mining Research 4(2):13-22.
Pacifico S, D'Abrosca B, Golino A, Mastellone C, Piccolella S, Fiorentino A, Monaco P (2008) Antioxidant evaluation of polyhydroxylated nerolidols from redroot pigweed (*Amaranthus retroflexus*) leaves. LWT-Food Science and Technology 41(9):1665-1671.
Pochron S, Choudhury M, Gomez R, Hussaini S, Illuzzi K, Mann M, Mezic M, Nikakis J, Tucker C (2019). Temperature and body mass drive earthworm (Eisenia fetida) sensitivity to a popular glyphosate-based herbicide. Applied Soil Ecology 139:32-39.
Poth M, Anderson IC, Miranda HS, Miranda AC, Riggan PJ (1995). The magnitude and persistence of soil NO, N2O, CH4, and CO2 fluxes from burned tropical savanna in Brazil. Global Biogeochemical Cycles 9(4):503-13.
Rose MT, Cavagnaro TR, Scanlan CA, Rose TJ, Vancov T, Kimber S, Kennedy IR, Kookana RS, Van Zwieten L. (2016). Impact of herbicides on soil biology and function. In Advances in agronomy Academic Press 136:133-220.
Rusu T (2014). Energy efficiency and soil conservation in conventional, minimum tillage and no-tillage. International Soil and Water Conservation Research 2(4):42-49.
Safarpour H, Asiaie R, Katz S (2004). Quantitative analysis of imazamox herbicide in environmental water samples by capillary electrophoresis electrospray ionization mass spectrometry. Journal of Chromatography 1036(2):217-222.
Schoch P, Binkley D (1986). Prescribed burning increased nitrogen availability in a mature loblolly pine stand. Forest Ecology and Management 14(1):13-22.
Sebiomo A, Ogundero VW, Bankole SA (2012) The impact of four herbicides on soil minerals. Research Journal of Environmental and Earth Sciences 4(6):617-624.
Seefeldt SS, Boydston RA, Kaspari PN, Zhang M, Carr E, Smeenk J, Barnes DL(2013) Aminopyralid residue impacts on potatoes and weeds. American Journal of Potato Research 90(3):239-244.
Shinn SL, Thill DC (2004). Tolerance of several perennial grasses to imazapic. Weed Technology 1:60-65.
Smith LM, Kok LT (1984). Dispersal of musk thistle (*Carduus nutans*) seeds. Weed Science 1:120-125.
Smith P, Heath D, Fishman AP (1976). Paraquat. CRC Critical Reviews in Toxicology 4(4):411-445.
Song Y (2014). Insight into the mode of action of 2, 4-dichlorophenoxyacetic acid (2, 4-D) as an herbicide. Journal of Integrative Plant Biology 56(2):106-113.
Stara A, Kubec J, Zuskova E, Buric M, Faggio C, Kouba A, Velisek J (2019). Effects of S-metolachlor and its degradation product metolachlor OA on marbled crayfish (*Procambarus virginalis*). Chemosphere 224:616-625.
Takano HK, Dayan FE (2019). Glufosinate-ammonium: a review of the current state of knowledge. Pest Management Science 76(12):3911-3925.
Thirunarayanan K, Zimdahl RL, Smika DE (1985). Chlorsulfuron adsorption and degradation in soil. Weed Science 1:558-563.
Thurman EM, Goolsby DA, Meyer MT, Kolpin DW (1991). Herbicides in surface waters of the midwestern United States: The effect of spring flush. Environmental Science and Technology 25(10):1794-1796.
Toni C, De Menezes CC, Loro VL, Clasen BE, Cattaneo R, Santi A, Pretto A, Zanella R, Leitemperger J (2010). Oxidative stress biomarkers in Cyprinus carpio exposed to commercial herbicide bispyribac-sodium. Journal of Applied Toxicology 30(6):590-5.
Vågen TG, Lal R, Singh BR (2005). Soil carbon sequestration in sub-Saharan Africa: a review. Land Degradation and Development. 16(1):53-71.
Van den Brink PJ, Hartgers EM, Fettweis U, Crum SJ, Van Donk E, Brock TC (1997). Sensitivity of macrophyte-dominated freshwater microcosms to chronic levels of the herbicide linuron. Ecotoxicology and Environmental Safety 38(1):13-24.
Villarroel MJ, Sancho E, Ferrando MD, Andreu E (2003) Acute, chronic and sublethal effects of the herbicide propanil on Daphnia magna. Chemosphere 53(8):857-864.
Wang B, Ding G, Zhu J, Zhang W, Guo M, Geng Q, Guo D, Cao Y. (2015). Development of novel ionic liquids based on bentazone. Tetrahedron 71(41):7860-7864.
Welch RY, Behnke GD, Davis AS, Masiunas J, Villamil MB (2016). Using cover crops in headlands of organic grain farms: Effects on soil properties, weeds and crop yields. Agriculture, Ecosystems and Environment 216:322-332.
Willoughby I, Clay D, Dixon F. (2003) The effect of pre-emergent herbicides on germination and early growth of broadleaved species used for direct seeding. Forestry 76(1):83-94.
Yu YL, Chen YX, Luo YM, Pan XD, He YF, Wong MH (2003). Rapid degradation of butachlor in wheat rhizosphere soil. Chemosphere. 50(6):771-774.
Yusof S, Ismail A, Alias MS (2014). Effect of glyphosate-based herbicide on early life stages of Java medaka (*Oryzias javanicus*): a potential tropical test fish. Marine Pollution Bulletin 85(2):494-498.
Zhang X, Wang H, He L, Lu K, Sarmah A, Li J, Bolan NS, Pei J, Huang H (2013). Using biochar for remediation of soils contaminated with heavy metals and organic pollutants. Environmental Science and Pollution Research 20(12):8472-8483.