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Tillage practices in the north west region of Cameroon and their consequences on soil physio-chemical properties - a review

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A B S T R A C T

Tillage practices make up one of the most essential operations executed on the soil during crop production. They manipulate the soil by mechanical means using tools, implements, and powered machinery with the intention to prepare the soil and make it suitable for plant growth. For the adoption of sustainable agriculture, tillage practices carried out in a particular region and their consequences on soil health need to be assessed. This review article identified traditional, conventional, and conservation tillage as the major tillage systems employed by farmers during crop cultivation in the North West Region of Cameroon. Traditional tillage practices (traditional ridging, burning in ridges ("Ankara"), and slash and burn) were highly predominant especially among small-holder farmers, followed by conservation tillage. Conventional tillage practices were the least practiced among farmers. Due to the less adoption of conventional and conservation tillage, soils in the region are mainly affected by the identified widely used traditional tillage practices. Traditional ridging exerted beneficial effects on the soil such as improved soil water conservation, increased soil nitrogen, and soil organic matter contents while burning in ridges and slash and burn exerted negative consequences on the soil by declining soil fertility, destroying soil physical properties and reducing overall land productivity. Due to the adoption of poor tillage techniques, soil degradation is rampant in the region placing the population at risk of low land productivity and food insecurity. The adaptation of improved tillage practices such as traditional ridging is thus required for sustainable soils and increased food security.

Keywords: Agriculture, Farming systems, Land sustainability, Soils, Tillage

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Introduction

Tillage is one of the initial and most vital operations carried out on the soil during crop production. Tillage practices make up half of the operations executed in the field annually (Sessiz *et al.*, 2010). With the intention of changing the soil structure, managing crop residues, killing weeds, and achieving some desired effect on the soil such as cutting, movement and pulverization, tillage operations manipulate the soil by mechanical means using tools, implements and powered machinery (Bekele, 2020). Tillage operations prepare the soil and make it suitable for plant growth by enabling a favorable environment for seed germination, seedling emergence, penetration and growth of plant roots (Barber, 2001). They also enable the incorporation of fertilizers or other soil amendments (Claassen *et al.*, 2018).

For centuries, tillage has been seen as a fundamental practice when it comes to producing crops (Baker *et al.*, 2007) and began with the use of simple hand tools such as the hand hoe by humans as the main farm implement (Dabo *et al.*, 1998). Animal traction later followed whereby animals such as cattle, horses, oxen, or donkeys (Dabo *et al.*, 1998) were used to pull simple implements such as wooden ploughs. Next were small tractors and motorized farm equipment (Dabo *et al.*, 1998), to the now sophisticated farm machinery consisting of heavy-duty farm tractors with different types of tractor-mounted multipurpose implements. Tillage practices are thus a labour-intensive activity carried out by small-holder farmers with low resources or a capital and energy-intensive activity carried out by highly resourceful mechanized farmers (Khursheed *et al.*, 2019).

Tillage practices have been categorized into systems. These tillage systems are defined based on the level of soil disturbance and the quantity of crop residue that is left on the soil surface after sowing. These are; conventional or intensive tillage, conservation tillage (Baker, 2011), and traditional tillage. Conventional tillage in the chronology of operations is divided into two separate operations which are primary tillage and secondary tillage (Barber, 2001). Primary tillage is the initial soil working operation and its operations are often referred to as ploughing while secondary tillage consists of tillage operations following primary tillage aimed at smoothening the soil (Phogat *et al.,* 2020). Conservation tillage practices include no-tillage, ridge tillage, reduced tillage, strip tillage and mulch tillage (Baker, 2011).

Tillage practices have considerable impacts on the availability of soil nutrients, seedling emergence and crop growth (Nweke, 2018), crop yields and soil physical properties (Ray and Rai, 2018). They exert physical, biological and chemical effects on the soil which are both degrading and beneficial depending on the methods used (Bekele, 2020). Tillage operations modify the soil structure, optimizing soil conditions and enhancing water infiltration (Nweke, 2018). They also aid in soil aeration and the conservation of soil and soil water (Baker *et al.,* 2007). However, tillage practices exert some negative consequences on the soil such as loss of soil moisture, soil organic matter degradation and soil compaction often experienced with conventional tillage (Kahlon and Khurana, 2017; Phogat *et al.,* 2020). Farmers apply different types of tillage practices based on their unique cultures. These tillage practices exert different effects on the soil and crop productivity varying from one agricultural zone to the other (Nweke, 2018). Assessing location-specific tillage practices aids in the adoption of better and more sustainable practices capable of enhancing crop production, soil health and land productivity. This review paper therefore evaluated the tillage practices carried out in the North West Region of Cameroon and their influence on soil physiochemical properties.

Description of the north west region of Cameroon

The North West Region of Cameroon is located in the western highlands agricultural zone of Cameroon (Ngu *et al.,* 2020). It is dominated by a range of mountains, situated at an average altitude of 1550 m above sea level and covering an estimated land area of 17300 km² (National Institute of Statistics of Cameroon, 2018). It has an average annual rainfall range of between 1600 to 2300 mm (Takoutsing *et al.,* 2015). Its climate is soft and fresh with temperatures oscillating around 22°C (National Institute of Statistics of Cameroon, 2018). The vegetation is predominantly savannah, and the main farming system is subsistence agriculture whereby small holder farmers cultivate diverse food crops by applying very little soil improvement practices (Takoutsing *et al.,* 2015). The main crops cultivated in the region are maize, beans, groundnuts, tomatoes, green vegetables, sweet potatoes, irish potatoes, okra, onions, cassava, watermelon, pepper, rice, yams, coffee, plantain and Bananas (National Institute of Statistics of Cameroon, 2018; Ngu *et al.,* 2020). Fig 1. presents the map of the North West Region of Cameroon of Cameroon and its seven divisions.

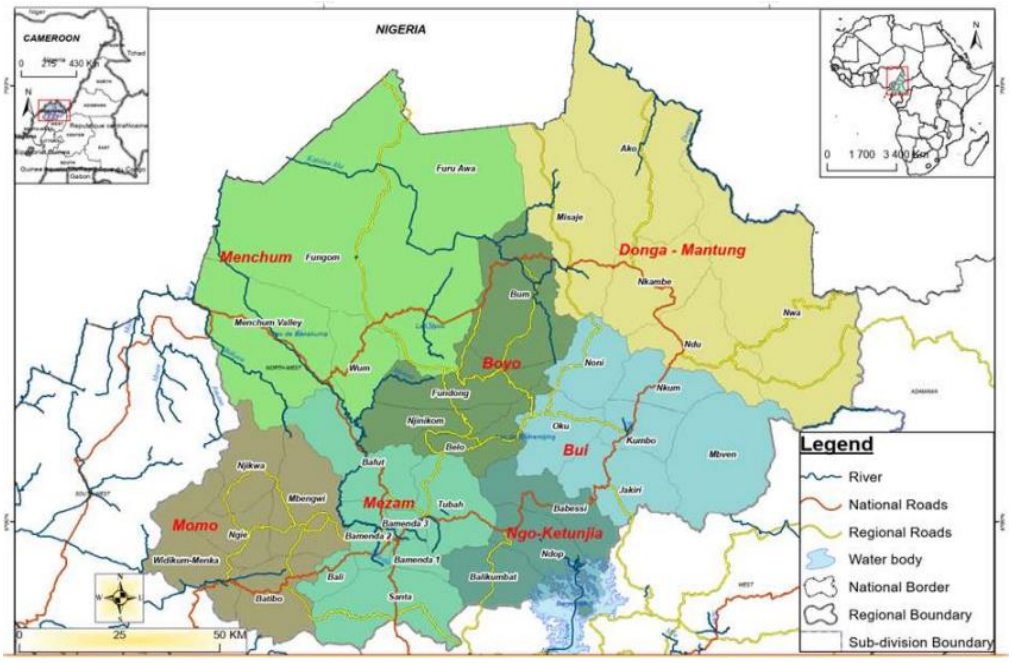

Fig. 1. Map of the North West Region of Cameroon.
Source: *National Institute of Statistics of Cameroon (2018)*

1.

Tillage practices in the north west region of Cameroon and their consequences on soil physiochemical properties

Traditional tillage

Traditional tillage involves indigenous tillage practices that are executed by mostly small-scale farmers with the use of rudimentary hand tools. These operations are often associated with so much drudgery and overall low productivity. Tillage in this system is highly labour-intensive as the small holder farmers do not have enough resources to acquire high-capital mechanization equipment (Khursheed *et al.*, 2019).

Traditional tillage is the highest tillage system practiced in the North West Region of Cameroon. A survey by Kum *et al.* (2021) reported that 98.1% of small holder farmers in the region practiced the traditional tillage system which involves traditional ridge tillage (ridging along the contours). Other reports indicated the use of other traditional tillage practices such as the burning in ridges (popularly called 'Ankara') and slash and burn (Bongajum and Suinyuy, 2015; Kometa and Kang, 2017; Robiglio *et al.*, 2010).

Traditional ridging (ridging along the contours)

Traditional ridging is the most common and widely adopted traditional /small-scale tillage practice executed by smallholder farmers for the production of a majority of crops in the North West Region of Cameroon (Kum *et al.*, 2021; Robiglio *et al.*, 2010). It is executed by slashing vegetation, gathering it into furrows, covering it with soil, and allowing it to decompose for some weeks before planting. Traditional ridging can be carried out both in the dry and rainy season because of the absence of any sort of burning.

Traditional ridging affects soil physiochemical properties. Beneficially, it improves soil physical properties such as aggregate stability and soil water conservation, as well as soil chemical properties such as increased soil nitrogen content, soil organic carbon and soil organic matter content (Coulibaly *et al.*, 2020). These soil benefits according to Coulibaly *et al.* (2020) are due to the decomposition of vegetation covered with soil.

Burning in ridges ("Ankara")

Burning in ridges popularly called "Ankara" is the second most practiced traditional tillage practice in the North West Region of Cameroon. "Ankara" comprises the underneath burning of grasses arranged in ridges and covered with soil (Kometa and Kang, 2017; Robiglio *et al.*, 2010). The process of Ankara making begins with the cutting down of shrubs and grasses which are allowed to fully dry. Subsequently, the dried grasses and shrubs are gathered in to piles or heaps and arranged in to ridges. Soil is then lifted by the small-holder farmer using a hand hoe and placed on the ridges formed from dried shrubs and fire is set beneath it (Bongajum and Suinyuy, 2015). This is usually done during the dry season for a few weeks to the commencement of rainfall, after which the Ankara ridges are planted when it begins to rain. The process of Ankara tillage in the North West Region of Cameroon is illustrated in Fig 2.

Fig. 2. The process of Ankara in smallholder farms in the North West Region of Cameroon.

A: Cleared and dried grasses and shrubs lying on the soil during the dry season
B: Cleared grasses and shrubs gathered and piled in furrows to form ridges
B1: Burning of vegetation underneath the soil to form "Ankara"

Source: Bongajum and Suinyuy (2015)

The burning of vegetation underneath soil ("Ankara") affects soil properties. Ankara degrades soil physical properties by decreasing soil moisture content (Hesammi *et al.,* 2014), and increasing soil dry bulk density (Heydari *et al.,* 2016). It also negatively affects soil chemical properties by reducing soil organic matter content (Akis, 2016), and decreasing the nitrogen content of the soil as a result of the burning (Li *et al.,* 2012). Beneficially, burning in ridges enhances soil fertility by increasing soil phosphorus content (Abdulraheem, 2020; Li *et al.,* 2012). It is as well reported to raise soil pH (Li *et al.,* 2012). Despite the benefits of burning in ridges, soil fertility is observed to drop and crop growth and yields reduced as the years go by (Bongajum and Suinyuy, 2015). Thus, farmers turn to fallow fields where the Ankara operation is carried out leading to reduced land productivity over the years.

Slash and burn

Slash and burn is the least used small-scale tillage practice, mainly executed in the sub-urban parts of Bamenda, the North West Region of Cameroon (Bongajum and Suinyuy, 2015). Farmers consider slash and burn as a method of land preparation (Santin and Doerr, 2016), used to clear the forest by burning newly felled vegetation in preparation for planting (Nigh and Diemont, 2013). This practice is mostly carried out during the dry season when the vegetation is fully dried up to enable easy burning. After burning the vegetation, the field is subsequently cultivated with the hand hoe or planted directly. No ridges are formed from dried grasses and no soil is placed on the grasses before burning, as is the case with Ankara. Fallow periods are common with the slash-and-burn farming system (Ebel, 2018). This is because the farmers will have to leave the farm for years to enable the regrowth of dense and woody vegetation, before they will slash and burn it before crop cultivation during the next cycle (Pollini, 2014). The number of years a field is left to fallow differs depending on the number of families practicing slash-and-burn agriculture, changes in land tenure, and population pressure (Ebel, 2018).

Slash and burn tillage practice exerts some influence on soil health. It can substantially change soil's physical and chemical characteristics (Santin and Doerr, 2016). According to Heydari *et al.* (2016), burning of biomass with fires leads to a rise in soil bulk density, a decrease in soil moisture content, a decrease in soil organic matter content and a loss of soil structure. Ebel (2018) reported similar results, adding that slash and burn increases soil pH and the leaching of soil nutrients. The detrimental influences of slash-and-burn tillage practice on the soil make it a relatively poor tillage technique that leads to lower soil and overall land productivity in the region.

Conservation tillage

Conservation tillage is a tillage system that covers 30% or more of the soil surface with residues of crops after sowing as a means of reducing soil erosion by water (CTIC, 2017). In the North West Region of Cameroon, 21.2% of farmers practiced tillage practices under the conservation tillage system; 13.7% practiced strip tillage, and 7.5% practiced no-tillage (Kum *et al.,* 2021). No-tillage practice allows the soil untouched or undisturbed in-between the previous harvest and the next planting (CTIC, 2017) except for the injection of nutrients (Khursheed *et al.,* 2019). Strip tillage on the other hand tills the soil minimally allowing soil and residue in strips (CTIC, 2017).

Conservation tillage practices influence the physical and chemical properties of the soil (Sessiz *et al.,* 2010). According to Claassen *et al.* (2018), conservation tillage conserves soil physical properties such as soil water by minimizing moisture loss, improving soil structure, and reducing soil erosion. It also conserves soil biology such as earthworms, and soil chemical properties such as soil nutrients (Baker *et al.,* 2007). No-tillage practice in particular benefits soil health through the absence of soil compaction and the enhancement of soil organic matter (Phogat *et al.,* 2020). Reduced costs of tillage machinery and equipment and energy costs are associated with conservation tillage (Claassen *et al.,* 2018). Thus, conservation tillage is a better option for sustainable soil and environmental management by farmers (Khalid *et al.,* 2019). Due to the little adoption of conservation tillage practices in the North West Region of Cameroon, the benefits of conservation tillage to soil health are experienced by a few, thus the need for increased adoption for soil sustainability in the region.

Conventional/Mechanized tillage

Conventional tillage is a tillage system that involves mechanical agitation of the soil to loosen it for suitable plant growth (Ray and Rai, 2018). Conventional tillage disturbs the entire soil surface and is performed prior to and/or during planting (CTIC, 2017). It inverts the upper soil completely with tractor-drawn ploughs (e.g. mouldboard plough, disc plough, chisel plough, rotary plough) followed by subsequent pulverization using secondary tillage implements such as disc harrows, spike or spring tine harrows (Phogat *et al.,* 2020).

Mechanized tillage practices are applied in the North West Region of Cameroon (Robiglio *et al.,* 2010), but to a very limited extent. According to Ngu *et al.* (2020), agricultural mechanization is applied only by 6.25% of farmers in Cameroon, with soil tillage machines being mainly the tractor-mounted ploughs, harrows and rototillers. From their study, very few Cameroonians own,

rent or share modern agricultural machinery. In terms of agricultural farm tractors per hectare, Cameroon lags developed and some developing countries. Many farmers and machinery operators in Cameroon attributed their degree of dissatisfaction with farm machinery application to a lack of financial means of affording farm tillage machines such as tractors and their implements, and the lack of physical access to the machines thus the low degree of adoption and application of mechanized tillage practices (Ngu *et al.,* 2020). However, the very few existing farms applying conventional tillage practices in the North West Region utilize the tractor (some commonly used models in the region being SONALIKA, and Massey Ferguson) and tractor-driven implements such as the mountable disc ploughs and disc harrows. The rocky and hilly terrain of the North West Region hinders mechanization meanwhile rainfall which is often heavy (Magha *et al.,* 2021) causes the erosion of intensely tilled soils.

Mechanized tillage practices exert considerable effects on the soil. Beneficially, conventional tillage breaks the shallow compacted layers through deep ploughing enabling better root development (Barber, 2001). Also, conventional tillage increases soil porosity enabling better water infiltration (Aikins and Afuakwa, 2012; Nweke, 2018). On the other hand, conventional tillage which involves intensive soil manipulation and burying of crop residues has caused more severe soil erosion and soil degradation leading to a fragile soil physical structure and low soil organic matter content (Kahlon and Khurana, 2017). Mechanized tillage operations leave the soil loose and bare, making it vulnerable to erosion, reduction in its ability to conserve water due to surface evaporation, and the loss of essential soil nutrients such as nitrogen (Ray and Rai, 2018). Intensive tillage in the long run causes compaction of subsurface soil thus limiting the development and penetration of roots as well as plant growth and yield (Phogat *et al.,* 2020). Conventional tillage practices thus have long term adverse effects on the soil (Reji *et al.,* 2012) as well as the requirement of the high cost of labor, equipment, and fuel in breaking compacted soil layers which is disadvantageous to the farmer (Barber, 2001). Since conventional tillage practices are far less executed in the North West Region of Cameroon, its effects on soil health are less felt in the region. A summary of tillage operations executed in the North West Region of Cameroon, and their influence on soil physio-chemical properties are shown in Table 1.

Table 1. Tillage practices carried out by farmers in the North West Region of Cameroon, their degree of practice by farmers, and their influence on soil physio-chemical properties.

Tillage system	Tillage types practiced	Degree of practice by farmers	Influence on soil physio-chemical properties
Traditional (manual) tillage	Traditional ridging (ridging along the contours).	Highly predominant	Improves soil aggregate stability, moisture content, nitrogen content, organic carbon, and organic matter content.
	Burning in ridges (Ankara).	Second most practiced	Increases bulk density, phosphorus content and soil pH. Destroys soil structure, and decreases soil moisture, soil organic matter and soil nitrogen content.
	Slash and burn.	Least practiced	Increases bulk density, and soil pH. Destroys soil structure, decreases soil moisture, and soil organic matter contents.
Conservation tillage	Strip tillage.	Most practiced	Retains soil moisture and soil structure. Enhances soil organic matter.
	No-tillage	Second most practiced	
Conventional tillage	Primary and secondary tillage	At a very limited extent	Decreased bulk density and total porosity. Reduction in soil moisture and the loss of essential soil nutrients such as nitrogen.

Conclusion

The three main tillage systems (traditional, conventional and conservation tillage systems) are practiced in the North West Region of Cameroon. The traditional tillage system is the most used and widely adopted by farmers followed by the conservation tillage system (strip tillage and no-tillage). Conventional /mechanized tillage practices are mentioned to be practiced but to a very limited extent because very few farmers own, rent or share modern agricultural machinery due to the lack of financial means of affording farm tillage machines such as tractors and their

implements. Due to the low adoption of conventional and conservation tillage systems in the North West Region of Cameroon, soils in the region are mainly affected by the identified widely used traditional tillage practices. However, traditional ridging and conservation tillage practices exert beneficial effects on the soil while intensive shifting cultivation with farrow periods and traditional tillage practices such as burning in ridges (Ankara) and slash and burn are considered unapproved and poor farming practices due to their ability to decline land productivity, destroy soil physical properties and soil fertility. Soil degradation is thus rampant in the North West Region of Cameroon, placing the population at risk of low land productivity and food security. Soil-friendly tillage practices such as traditional ridging and conservation tillage are thus recommended for long-term land productivity.

References

Abdulraheem, M.I. 2020. Effects of ash on soil properties and yield of crops. *Agric. Obs.* 1(3): 61-66.

Aikins, S.H.M. and Afuakwa, J.J. 2012. Effect of four different tillage practices on soil physical properties under cowpea. *Agric. Biol. J. North America*. 3(1): 17 - 24. http://dx.doi.org/10.5251/abjna.2012.3.1.17.24

Akis, R. 2016. Effects of crop residue burning on soil physical and hydrological properties in semi-arid agricultural production systems. *J. Agril. Facul. Gaziosmanpasa Univ.* 33(3): 223-235. https://doi.org/10.13002/jafag1105

Baker, C.J., Saxton, K.E., Ritchie, W.R., Chamen, W.C.T., Reicosky, D.C., Ribeiro, M.F.S., Justice, S.E. and Hobbs, P.R. 2007. No-tillage seeding in conservation agriculture (2 ed.). CAB International and FAO. pp. 1-13.

Baker, N.T. 2011. Tillage practices in the conterminous United States, 1989-2004 - Datasets Aggregated by Watershed. *U. S.* Geological Survey Data Series 573, pp. 1-13. http://dx.doi.org/10.3133/ds573

Barber, R.G. 2001. Guidelines and reference materials for promoting integrated soil and nutrient management in Farmer Field Schools - Reference material for the module on Tillage. Food and Agriculture Organization of the United Nations, Rome. pp. 1-164.

Bekele, D. 2020. The effect of tillage on soil moisture conservation: a review. *Int. J. Res. Stud. Agril. Sci.* 6(10): 30-41.

Bongajum, S.N. and Suinyuy, D.G. 2015. Urban agriculture and landscape challenges in african cities: An illustration of the Bamenda City Council, Cameroon. *J. Pover. Invest. Dev.* 15: 55-72.

Claassen, R., Bowman, M., McFadden, J., Smith, D. and Wallander, S. 2018. Tillage intensity and conservation cropping in the United States. EIB-197, United States Department of Agriculture, Economic Research Service. pp. 1-21.

Coulibaly, S.S., Touré, M., Kouamé, A.E., Kambou, I.C., Soro, S.Y., Yéo, K.I. and Koné, S. 2020. Incorporation of crop residues into soil: a practice to improve soil chemical properties. *Agril. Sci.* 11: 1186-1198. https://doi.org/10.4236/as.2020.1112078

CTIC. 2017. Tillage Type Definitions. Conservation Technology Information Center. Retrieved 17/01 from http://www.ctic.purdue.edu/resourcedisplay/322

Dabo, B.M., Dieng, A.F., BaFall, T., Ka, A.N., Mbaye, B.S., Mboup, B., Ndiaye, F.K. and Sane, M. 1998. Agricultural implements used by women farmers in Africa. Desktop Publishing Team of IFAD (International Fund for Agricultural Development). Rome. pp. 1-136.

Ebel, R. 2018. Effects of Slash-and-Burn-Farming and a Fire-Free Management on a Cambisol in a Traditional Maya Farming System. *CIENCIA ergo-sum*. 25(2): 1-15. http://dx.doi.org/10.30878/ces.v25n2a5

Hesammi, E., Talebi, A.B. and Hesammi, A. 2014. A review on the burning of crop residue on the soil properties. *WALIA J.* 30(1): 192-194.

Heydari, M., Rostamy, A., Najafi, F. and Dey, D. C. 2016. Effect of fire severity on physical and biochemical soil properties in Zagros oak (*Quercus brantii* Lindl.) forests in Iran. *J. Forest. Res.* 28(1): 95-105. http://dx.doi.org/10.1007/s11676-016-0299-x

Kahlon, M.S. and Khurana, K. 2017. Effect of land management practices on physical properties of soil and water productivity in wheat maize system of Northwest India. *Appl. Ecol. Environ. Res.* 15(4): 1-13. http://dx.doi.org/10.15666/aeer/1504_001013

Khalid, A.A., Tuffour, H.O., Abubakariand, A. and Novor, S. 2019. Conservation tillage and organic matter management on soil structure. *Madridge J. Agril. Environ. Sci.* 1(1): 14-18. http://dx.doi.org/10.18689/mjaes-1000103

Khursheed, S., Simmons, C., Wani, S.A., Ali, T., Raina, S.K. and Najar, G.R. 2019. Conservation tillage: impacts on soil physical conditions–an overview. *Adv. Plants Agril. Res.* 9(2): 342–346.

Kometa, S.S. and Kang, E.M. 2017. Constraints to agricultural advancement within the Ndop Plain North West Region, Cameroon. *J. Biol. Agric. Healthcare*. 7(20): 1-8.

Kum, C.T., Tening, A.S., Ngwabie, M. and Tsamo, C. 2021. Sustainable farming practices: knowledge and practices of smallholder farmers in Bamenda Highlands, Cameroon. *Curr. J. Appl. Sci. Tech.* 40(24): 26-39. http://dx.doi.org/10.9734/cjast/2021/v40i2431500

Li, I., Ishikawa, Y. and Mihara, M. 2012. Effects of burning crop residues on soil quality in Wenshui, Shanxi of China. *Int. J. Environ. Rural Dev*. 3(1): 30-35.

Magha, A.M., Tamfuh, P.A., Mamdem, L.E., Yefon, M.C.S., Kenzong, B. and Bitom, D. 2021. Soil water characteristics of Gleysols in the Bamenda (Cameroon) wetlands and implications for agricultural management strategies. *Appl. Environ. Sci.* 2021: 1-15. http://dx.doi.org/10.1155/2021/6643208

National Institute of Statistics of Cameroon. 2018. Statistical Yearbook for the North West Region. Yaoundé-Cameroon Retrieved from www.statistics-cameroon.org;www.stat.com

Ngu, J.L., Ousmane, M. and Saidou, I. 2020. Insight into agricultural mechanization in Cameroon: Case of farm operators, users of agricultural equipment and machines. *Int. J. Engin. Res. Sci.* 6(1): 1-10.

Nigh, R. and Diemont, S.A.W. 2013. The Maya milpa: fire and the legacy of living soil. *Front Ecol. Environ*. 11(1): 45-54. http://dx.doi.org/10.1890/120344

Nweke, I.A. 2018. The Good, the Bad and the Ugly of Tillage in Agricultural Sustainability - A Review. *Greener J. Agril. Sci.* 8(9): 217-250. http://dx.doi.org/10.15580/gjas.2018.9.090618130

Phogat, M., Dahiya, R., Sangwan, P.S. and Goyal, V. 2020. Zero tillage and water productivity: A review. *Int. J. Chem. Stud.* 8(5): 2529-2533. http://dx.doi.org/10.22271/chemi.2020.v8.i5ai.10698

Pollini, J. 2014. Slash-and-Burn Agriculture. In: Thompson, P., Kaplan, D. (eds) Encyclopedia of Food and Agricultural Ethics. Springer, Dordrecht. http://dx.doi.org/10.1007/978-94-007-6167-4_87-1

Ray, A. and Rai, A. 2018. Effect of different tillage practices on soil health and yield. *Trends in Biosci.* 11(11): 2107 – 2112.

Reji, P.M., Feng, Y., Githinji, L., Ankumah, R. and Balkcom, K.S. 2012. Impact of no-tillage and conventional tillage systems on soil microbial communities. *Appl. Environ. Soil Sci.* 2012: 1-10. http://dx.doi.org/10.1155/2012/548620

Robiglio, V., Ngendakumana, S., Yemefack, M., Tchienkoua, M., Gockowski, J. and Tchawa, P. 2010. Options for reducing emissions from all land uses in Cameroon. World Agroforestry Centre, United Nations Avenue. pp. 1-114.

Santin, C. and Doerr, S.H. 2016. Fire effects on soils, the human dimension. *Philosop. Trans. Royal Soc.* 371: 1-10.

Sessiz, A., Alp, A. and Gursoy, S. 2010. Conservation and conventional tillage methods on selected soil physical properties and corn (*Zea mays* L.) yield and quality under cropping system in Turkey. *Bulgarian J. Agril. Sci.* 16(5): 597-608.

Takoutsing, B., Ayenkulu, E., Tchoundjeu, Z., Coe, R., Nna, D. and Shepherd, K. 2015. Land health surveillance for identifying land constraints and targeting agroforestry intervention in smallholder farming systems in Western Cameroon ICRAF Working Paper No. 191, Yaounde. pp. 1-40. http://dx.doi.org/10.5716/wp14253.pdf