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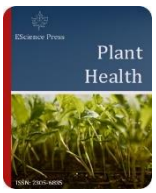

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An Insight into Importance, Sources and Types of Manures

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ABSTRACT

There is an increasing awareness regarding organic farming in the world. But, Pakistani farmers yet to be realize about worst effect of modern agricultural practice. Hence alternative types of farming particularly the organic farming is hour of the need to get rid of inorganic fertilizers, chemicals, pesticides and some growth regulators etc. Manure has been utilized for centuries as a chief source of nutrients in agriculture. However, soil properties that mainly contribute to improve soil health are affected by application of manure i.e. Bulk density, soil aggregate stability, infiltration, soil water holding capacity, and biological properties are impacted to numerous degrees with manure application. Imbalance application of inorganic fertilizers and or no application of organic fertilizers can easily loosen the soil and elevate erosion and loss soil fertility. Inorganic fertilizers losses from agricultural field are more and also act as major source of atmospheric pollution. Therefore, proper application of organic and inorganic fertilizers can improve soil properties and fertility. Manure provides all essential nutrients required by plants but in limited quantities. It helps in maintaining C:N ratio in soil and also increases soil fertility and productivity. Due to increase in biological activity, nutrients that are in lower depths are easily available for plants. It also acts as much, thereby minimizing evaporation losses from the soil.

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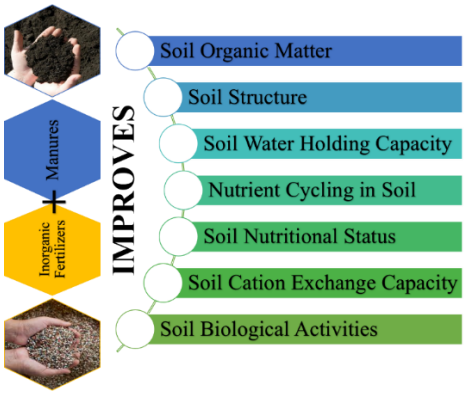
INTRODUCTION

Manure is rich in plant nutrients, readily obtained, and can reduce the reliance on mineral fertilizer. In the ancient times, farmers used to rely on organically produced manures for production of crops that proved excellent for health of soil but the response was slow on the crop yields thus it was insufficient to meet demand of food of ever increasing population. In this era, swift economic development has led farmers to apply inorganic fertilizers as these are easier to apply, economical, affordable and their response is quick. The word "*manure*" is derived from a French word "*Manoeuvrer*" which means to work or manipulate (Thompson, 1968) and generally meaning of manure is animal's excreta or decomposed plants and dead animals (Parihar *et al.,* 2019). Manures are rich in organic matter as well as humus thus they are used for improving soil fertility (Brust, 2019). Organic manure mainly includes such materials that have natural origin with organic composition (Ibeawuchi *et al.,* 2015), having higher nutrients content (Antil and Singh, 2007), used to increase soil nutritional status as well as soil organic matter content and increase crop production (Adugna, 2016) (Figure 1). Manures are also known as natural fertilizer and they are cost-effective as they are mainly obtained by natural products (Mazid and Khan, 2015). They are environmental friendly and helped in escalating the agriculture production of world as it was quite

difficult to feed the rapidly increasing world population (Tilman and Clark, 2015). Manure also has a high number of fibers as animals feed that left undigested like straw, sawdust or some other bedding contains higher amounts of fiber (Abd Manaf *et al.,* 2009). However, about 78% of the N from livestock excreta is lost to the environment (Bai *et al.,* 2016), so an alternative management strategy to substitute mineral fertilizer with manure is necessary. So, farmers can easily sell manure to the people who need to improve fertility of their soils. Thus, it can also bring income to the farmers. Use of organic manures improved soil fertility and increased crop yield. Manures are of different kinds i.e. solid manures have approximately 26% solid while solid portion and liquid manure are segregated; solids are mainly used as bedding while carbon content and some other elements in manure can be used for the production of different kinds of biofuels (Shanka, 2020).

Importance of Manures

Manures are beneficial for soils and crops (Fageria, 2007). Recently, there has been an increasing interest in the use of organic nutrient sources and soil amendments have been increased (Park *et al.,* 2011). The fact that they are commonly using because they are a good source of carbon (C) (Chandra, 2005) which plays a role in improving soil quality and climate change mitigation (Rayne and Aula, 2020). Manure has been promoted as a viable substitution for mineral fertilizers to increase food security (Akinnifesi *et al.,* 2010), increase the sequestration of C in the soil, maintain soil structure and fertility (Riley *et al.,* 2008) and reduce mineral fertilizer inputs and harmful environmental impacts (Du *et al.,* 2020). Use of manures alongside the inorganic fertilizers lead to increase the organic matter in soil, improved soil structure, increased soil water holding capacity and rapid the nutrient cycling that helps to maintain the soil nutritional status, soil cation exchange capacity and all the biological activities which are happening in the soil.



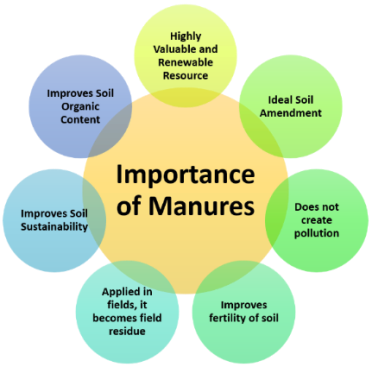


Figure 1. Importance of manures in Agriculture.

The physicochemical and biological properties of the soil, such as pH, bulk density (BD), enzymatic activity, aggregation, soil organic carbon (SOC), total N (TN), available N (AN), available phosphorus (AP), and available potassium (AK) contents are strongly affected by the application of manures (Ye *et al.,* 2019). Changes in the soil properties indicate the sustainability of soil productivity that will inevitably affect crop yield (Cai *et al.,* 2019). Manure application represent a sustainable development strategy to improve soil and crop productivity and increase yield of crops (Du *et al.,* 2020). Manure contains abundant nutrients and binding agents that increase soil fertility and enzymatic activities and improves the soil structure (Wang *et al.,* 2017). When structure of soil is improved then growth of root will be better and a better root growth ultimately improves crop growth and yield by uptake of sufficient water and nutrients from soil. Organic manure not only increases soil carbon inputs but they also influences residues of crops, which determine benefits of SOC sequestration and release of nutrients (Kuzyakov and Blagodatskaya, 2015). Apparently, organic manure treatments can improve SOC and nutritional status of soils for the long-term cropping.

Sources of Manure

Manure can be obtained from various sources. The different sources of manure are given below in figure 2.

Types of Manure

These are the type of manures which are given below and a detailed overview is given on every type.

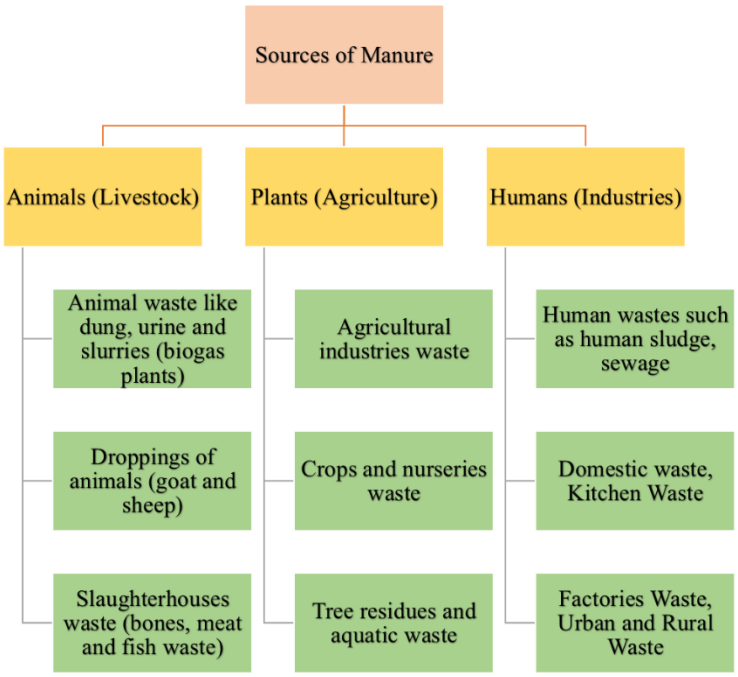


Figure 2. Source of different types of manures.

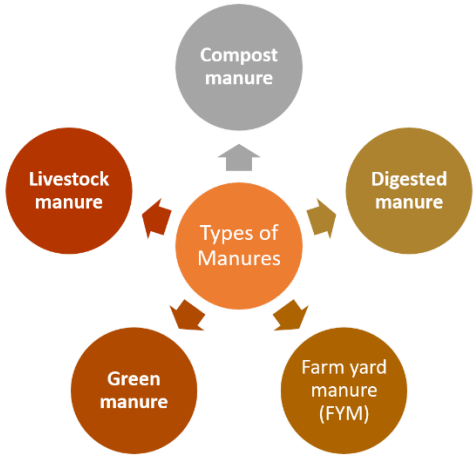


Figure 3. Source of different types of manures.

Compost Manure

Composting is a traditional waste management process (Hottle *et al.,* 2015) that is used since very long time to decompose organic matter by aerobic process in the presence of microbes (Ayilara *et al.,* 2020). The major reasons of composting are recycling of nutrients that are excreted by the animals, stabilization of organic matter before its transport/use and reduction of pathogens present in manure (Bernal *et al.,* 2009). It takes three months to convert manure into the compost under special environment (Ahmad *et al.,* 2021). If the conditions during process are not optimum, then it might take more than 6 months for composting. Manure of horses is known as best manure to be converted into the compost (Airaksinen *et al.,* 2001). It only takes about 4 to 6 weeks for the composting. Composting is done in special windrows with turning or forced aeration. Vermicomposting is also a good option, but it is marginal. Waste of poultry farms is also used for composting, that includes microbial inoculation (Ichida *et al.,* 2001). Generally, cattle manure is used for composting by the farmers with the help of a truing machine. Another type

of livestock composting is known as "co-composting" that is based on territorial partnership between farmers or maybe a group of farmers with local communities (Loyon, 2017). Among the organic manures, cattle manure has been used in the agricultural fields widely and composted form of cattle manure is mostly preferred over fresh one, to eliminate risks of nitrogen loss through leaching/surface runoff, increase organic matter in soil, suppress soil-borne diseases/pathogens and to mitigate emission of greenhouse gases (Escribano, 2016).

The compost of livestock waste with minimum usage of chemical fertilizer as soil amendment in the low-input intensive farming has been well recognized as vital practice to enhance fertility and productivity of soil (Kravchenko *et al.,* 2017). Noteworthy, key benefits of these practices rely on changes in soil microbial activities that play key role in mobilization of nutrients and promotion of plant growth (Sun *et al.,* 2015). Nonetheless, animal waste composts is used to manage microbial communities in soil like presence of beneficial and absence of detrimental soil microorganism may improve fertility and productivity of soils (Hartmann *et al.,* 2015). Some previous studies revealed that application of animal waste composts either alone or combined with in-organic fertilizers, improved enzymatic activities and soil bacterial diversities (Zhang *et al.,* 2015). Sun et al. (2015) said that application of chemical fertilizers like NPK for long-term caused a significant ($p < 0.05$) decrease of soil bacterial diversity, whereas addition of manure restored soil bacterial diversity.

Li et al. (2017) suggested that combined application of organic cattle manure compost and in-organic fertilizer (NPK), not only improved SOC and total nitrogen but also it enhanced soil bacterial community that is implicated in decomposition of organic matter and carbon, nitrogen, and phosphorus transformations in soil. While the effects nutritional changes and their availability because of fertilization on soil microbial communities have received some considerable attention, as specific microbial taxa were strongly influenced by animal manure compost fertilization and soil fertility was also influenced in the flooded rice paddy systems.

Digested Manure

Farm waste is digested anaerobically that includes livestock manure, it is currently promising technique for the production of biogas, leading to liquid and solid digestate that used in the agriculture (Jin *et al.,* 2017). It is used as an alternative of in-organic fertilizers by the farmers (Caracciolo *et al.,* 2015). It is involved in energy production, another advantage of an-aerobic digestion is absence or significant reduction of pathogens in digestate (Xu *et al.,* 2020) and a complete recycling of waste. This practice is environmental friendly, used in the organic farming and it does not exclude likelihood of introducing soil antibiotics (Goulas *et al.,* 2017). Consequently, this is very crucial to assess potential risk of spreading antibiotic resistance by application of an-aerobically digested manure on the agricultural land. Once present in environment, antibiotics can harm natural microbial communities and populations (Cleary *et al.,* 2016).

An-aerobic digestion meant by transformation of carbon (20–95 %) in feedstock into the gaseous carbon compounds, depending on the kind and recalcitrance of that feedstock. Digestates are used as fertilizer for crops. Digestion of animal manures and crop residues reduce amounts of organic carbon that is introduced into soil in the comparison to direct incorporation in the soil of un-digested feedstock (Xu *et al.,* 2020). However, digestion can increase inputs of organic matter. Simultaneously, anaerobic digestion of manure leads to stabilize manure pH and transformation of nitrogen compounds (Möller and Müller 2012).

Farmyard manure (FYM)

Farmyard manures are traditionally applied to the root crops although it might be more beneficial to use them for the cash crops. Management of manures within rotation has been shown the larger effects on yield and quality of product, including levels of protein in cereals (Watson *et al.,* 2012). Effect of organic and in-organic chemical fertilizers on properties of soil and yield of rice as well as wheat grain was studied after eight years of the cropping cycle on soil having loamy sand texture. Incorporation of crops residue along with NPK (50%) and farmyard manure contributed to wards meeting 50% requirement NPK for rice crop (Bhattacharyya *et al.,* 2015). Application of farmyard manure and crop residues over a long-term increased SOC content (Ding *et al.,* 2014) and significantly improved availability of nitrogen, phosphorus, potassium, sulfur and other soil micronutrients (Thomas *et al.,* 2019).

Huang et al. (2010) reported that incorporation of farmyard manures not only improved production of crop but also slow down rate of soil acidification in the agricultural ecosystems. Addition of farm yard manure and integrated use of farm yard manure with inorganic fertilizers resulted in the significantly higher

accumulation of organic carbon over the in-organic fertilizer alone, after harvesting of maize crop under maize-wheat cropping system (Kumari *et al.,* 2013). Francioli et al. (2016) described that as compared to in-organic fertilizer, the integrated application of inorganic fertilizer with 22.0 % lower than the recommended dose along with farmyard manure (20t ha-1) includes solid cattle manure with the bedding increased soil organic matter contents, total nitrogen content and soil microbial biomass carbon significantly ($p < 0.05$) while the crop yield was at par. Li et al. (2017) concluded that application of NPK + manure increased soil total organic carbon by 143.4 and 54.7%, total nitrogen by 134.0 and 78.3% and yield of crop by 48.9 and 39.6%, respectively, as compared to in-organic fertilization of NPK.

Green Manure

A green manure is known as a crop that is used primarily as soil amendment and as a source of nutrient for subsequent crops. Green manures are agricultural crops that are grown specifically for the building and maintaining of soil fertility and soil structure (Brust *et al.,* 2019; Watson *et al.,* 2002) so they also affect some other important functions occurring within soil system. These are normally incorporated back into soil directly or after removal of crops (Thiessen Martens and Entz, 2011). In most of the countries green manures have generally used little by the conventional or non-organic producers but being enthusiastically adopted by the organic producers.

Green manure approaches to production of crop that may improve economic viability (Cherr *et al.,* 2006) and it reduce agricultural environmental impacts (Fageria, 2007). However, such approaches are really complex as these are dependent on the interactions between green manure, the environment and or management (Ma *et al.,* 2021). Leguminosae species are commonly used as green manure because they accumulate large amounts of N in their biomass through N fixation (Valadares *et al.,* 2016; Ali and Tahir, 2021). In addition, legumes provide biomass with a low C:N ratio, leading to rapid N mineralization after incorporation, and positive effects on N nutrition even in the early stages of growth of the following crop (Dawson *et al.,* 2008). Green manures have ability to replace some, or all of the nitrogen required for the non-leguminous succeeding crops.

Application of green manures into soil is considered as a good management practice in agricultural production system as it stimulates microbial growth and activities in soil, increase soil organic matter content, preserve the physical nature of the soil and improve soil fertility and crop yield (Adekiya *et al.,* 2020). Leguminous and non-leguminous plants are being used as "green manures". Leguminous green manures have ability to fix large amounts of atmospheric N2 and it provide higher amounts of soil organic matter. Non-leguminous green manures only can improve soil organic matter contents and they do not fix atmospheric N2. For this major reason, beet vinasse may be overcome by co-composting with green manures.

A large number of studies have proved the positive effects of green manure application on improving agricultural production in different areas (Yang *et al.,* 2018). The beneficial effects can be summarized as follows: 1) preventing soil erosion and decreasing the runoff from farmland in the fallow period (Sharratt *et al.,* 2018) reducing soil bulk density and increasing the content of soil organic matter, soil nitrogen, soil phosphorus, soil potassium and other nutrients, and thus reducing the use of chemical fertilizers (Chaudhary *et al.,* 2017).

Livestock Manure

The manure of livestock is rich in essential nutrients like nitrogen, phosphorus, potassium and carbon for plants (Pagliari and Laboski, 2012) it can increase the burning issue of global climate change via methane (CH4) and nitrous oxide (N_2O) emissions. Farm animals void most of the nitrogen, phosphorus, and potassium which is present in food they eat and that food constitutes an enormous resources of fertility. By definition, animal manure is excreta of animals (urine and feces) and also the bedding materials that is usually applied in to the soils as an organic fertilizer for the agricultural production.

Animal manure may also have some dropped feed, water and soil that totally depend upon the livestock management practices. Since beginning of agricultural activities by the humans over thousands years ago, animal manure has been used as an integrated part of crop production on sustainable basis (Bogaard *et al.,* 2013). Before the extensive in-organic fertilizer manufacturing, majority of the out-sourced crop nutritional inputs were from the manures of farm animals. However, current environmental impact of generation and disposal of manures extends beyond the simple organic fertilizers, as more manure is produced in the large, confined animal feeding operations (CAFO) than it can be cost-effectively transported to the cropland beyond feeding farms. It was also estimated that high animal numbers at the farm would produce a total of 9

$\times 10^9$ Mg of manure per annum.

Another aspect to consider is effect of changing composition of dietary feedstuff on resulting manure. Modern understanding of nutrition by animal, improve processing and technologies of feed, and also increased availability of distillers by-products and some other alternative feedstuffs also resulted in special diets containing nutrients that are more readily available and have synthetic additives for prevention of disease and they also promote growth than the traditional feed of animals, which ultimately end up in the "Manure" (Song and Guo, 2014).

CONCLUSION

Sustainable production systems require the control of environmental losses and the spread of contaminants from livestock manure management. Conversion mechanism of changing waste material into useful products such as manure is the demand of today's agriculture to enhance the soil fertility and soil physical and chemical properties. It will enhance plants growth and beneficial for animals.

REFERENCES

Abd Manaf, L., M. L. C. Jusoh, M. K. Yusoff, T. H. T. Ismail, R. Harun, H. Juahir and K. Jusoff. 2009. Influences of bedding material in vermicomposting process. *International Journal of Biology*, *1*(1): 81.

Adekiya, A. O., T. M. Agbede, W. S. Ejue, C. M. Aboyeji, O. Dunsin, C. O. Aremu and O. O. Adesola. 2020. Biochar, poultry manure and NPK fertilizer: sole and combine application effects on soil properties and ginger (Zingiber officinale Roscoe) performance in a tropical Alfisol. *Open Agriculture*, *5*(1): 30-39.

Adugna, G. 2016. A review on impact of compost on soil properties, water use and crop productivity. *Academic Research Journal of Agricultural Science and Research*, *4*(3): 93-104.

Ahmad, A., Z. Aslam, K. Bellitürk, N. Iqbal, M. Idrees, M. Nawaz and M. M. Aziz. 2021. Earth worms and vermicomposting: A review on the story of black gold. *Journal of Innovative Sciences*, *7*(1): 167-173.

Airaksinen, S., H. Heinonen-Tanski and M. L. Heiskanen. 2001. Quality of different bedding materials and their influence on the compostability of horse manure. *Journal of equine veterinary science*, *21*(3): 125-130.

Akinnifesi, F. K., O. C. Ajayi, G. Sileshi, P. W. Chirwa and J. Chianu. 2010. Fertiliser trees for sustainable food security in the maize-based production systems of East and Southern Africa. A review. *Agronomy for sustainable development*, *30*(3): 615-629.

Ali, M. F. and M. Tahir. 2021. An Overview on the Factors Affecting Water-soluble Carbohydrates Concentration during Ensiling of Silage. *Journal of Plant and Environment*, *3*(1): 63-80.

Antil, R. S. and M. Singh. 2007. Effects of organic manures and fertilizers on organic matter and nutrients status of the soil. *Archives of Agronomy and Soil Science*, *53*(5): 519-528.

Ayilara, M. S., O. S. Olanrewaju, O. O. Babalola and O. Odeyemi. 2020. Waste management through composting: Challenges and potentials. *Sustainability*, *12*(11): 4456.

Bai, Z., L. Ma, S. Jin, W. Ma, G. L. Velthof, O. Oenema and F. Zhang. 2016. Nitrogen, phosphorus, and potassium flows through the manure management chain in China. *Environmental science and technology*, *50*(24): 13409-13418.

Bernal, M. P., J. A. Alburquerqu and R. Moral. 2009. Composting of animal manures and chemical criteria for compost maturity assessment. A review. *Bioresource technology*, *100*(22): 5444-5453.

Bhattacharyya, R., B. N. Ghosh, P. K. Mishra, B. Mandal, C. S. Rao, D. Sarkar and A. J. Franzluebbers. 2015. Soil degradation in India: Challenges and potential solutions. *Sustainability*, *7*(4): 3528-3570.

Bogaard, A., R. Fraser, T. H. Heaton, M. Wallace, P. Vaiglova, M. Charles, G. Jones, R. P. Evershed, A.K. Styring, N. H. Andersen and R. M. Arbogast. 2013. Crop manuring and intensive land management by Europe's first farmers. *Proceedings of the National Academy of Sciences*, *110*(31): pp.12589-12594.

Brust, G. E. 2019. Management strategies for organic vegetable fertility. In *Safety and practice for organic food* (pp. 193-212). Academic Press.

Cai, A., M. Xu, B. Wang, W. Zhang, G. Liang, E. Hou and Y. Luo. 2019. Manure acts as a better fertilizer for increasing crop yields than synthetic fertilizer does by improving soil fertility. *Soil and Tillage Research*, *189*: 168-175.

Caracciolo, A. B., M. A. Bustamante, I. Nogues, M. Di Lenola, M. L. Luprano and P. Grenni. 2015. Changes in microbial community structure and functioning of

a semiarid soil due to the use of anaerobic digestate derived composts and rosemary plants. *Geoderma*, *245*: 89-97.

Chandra, K. 2005. Organic manures. *Booklet Released on the Occasion of*, *10*.

Chaudhary, S., G. S. Dheri and B. S. Brar. 2017. Long-term effects of NPK fertilizers and organic manures on carbon stabilization and management index under rice-wheat cropping system. *Soil and Tillage Research*, *166*: 59-66.

Cherr, C. M. J. M. S. Scholberg and R. McSorley. 2006. Green manure approaches to crop production: A synthesis. *Agronomy journal*, *98*(2): 302-319.

Cleary, D. W., A. H. Bishop, L. Zhang, E. Topp, E. M. Wellington and W. H. Gaze. 2016. Long-term antibiotic exposure in soil is associated with changes in microbial community structure and prevalence of class 1 integrons. *FEMS microbiology ecology*, *92*(10).

Dawson, J. C., D. R. Huggins and S. S. Jones. 2008. Characterizing nitrogen use efficiency in natural and agricultural ecosystems to improve the performance of cereal crops in low-input and organic agricultural systems. *Field Crops Research*, *107*(2): 89-101.

Ding, X., Y. Yuan, Y. Liang, L. Li and X. Han. 2014. Impact of long-term application of manure, crop residue, and mineral fertilizer on organic carbon pools and crop yields in a Mollisol. *Journal of Soils and Sediments*, *14*(5): 854-859.

Du, Y., B. Cui, Z. Wang, J. Sun and W. Niu. 2020. Effects of manure fertilizer on crop yield and soil properties in China: A meta-analysis. *Catena*, *193*: 104617.

Escribano, A. J. 2016. Organic livestock farming – challenges, perspectives, and strategies to increase its contribution to the agrifood system's sustainability – a review, in *Organic Farming – A Promising Way of Food Production*, ed. P. Konvalina (Rijeka: InTech). doi: 10.5772/61272.

Fageria, N. K. 2007. Green manuring in crop production. *Journal of plant nutrition*, *30*(5): 691-719.

Francioli, D., E. Schulz, G. Lentendu, T. Wubet, F. Buscot and T. Reitz. 2016. Mineral vs. organic amendments: Microbial community structure, activity and abundance of agriculturally relevant microbes are driven by long-term fertilization strategies. *Frontiers in Microbiol,* 7: 1446. doi:10.3389/fmicb.2016.01446.

Goulas, A., M. Bourdat-Deschamps, S. Nelieu, J. Jimenez, D. Patureau, C. S. Haudin and P. Benoit. 2017. Development of a soft extraction method for sulfamethoxazole and transformation products from agricultural soils: effects of organic matter co-extraction on the environmental availability assessment. *Science of The Total Environment*, *607*: 1037-1048.

Hartmann, M., B. Frey, J. Mayer, P. Mader and F. Widmer. 2015. Distinct soil microbial diversity under long-term organic and conventional farming. *International Society for Microbial Ecology Journal,* 9: 1177–1194.

Hottle, T. A., M. M. Bilec, N. R. Brown and A. E. Landis. 2015. Toward zero waste: Composting and recycling for sustainable venue-based events. *Waste Management*, *38*: 86-94.

Huang, S., W. Zhang, X. Yu and Q. Huang. 2010. Effects of long-term fertilization on corn productivity and its sustainability in an Ultisol of southern China. *Agriculture, ecosystems and environment*, *138*(1-2): 44-50.

Ibeawuchi, I. I., U. P. Iwuanyanwu, E. O. Nze, O. C. Olejeme and G. O. Ihejirika. 2015. Mulches and organic manures as renewable energy sources for sustainable farming. *Journal of Natural Sciences Research*, *5*(2): 139-147.

Ichida, J. M., L. Krizova, C. A. LeFevre, H. M. Keener, D. L. Elwell and E. H. Burtt Jr. 2001. Bacterial inoculum enhances keratin degradation and biofilm formation in poultry compost. *Journal of Microbiological Methods*, *47*(2): 199-208.

Jin, H., C. Xu, J. Du, H. Wu, H. Huang, Z. Chang and L. Zhou. 2017. Distribution of sulfonamides in liquid and solid anaerobic digestates: effects of hydraulic retention time and swine manure to rice straw ratio. *Bioprocess and biosystems engineering*, *40*(2): 319-330.

Kravchenko, A. N., S. S. Snapp and G. P. Robertson. 2017. Field-scale experiments reveal persistent yield gaps in low-input and organic cropping systems. *Proceedings of the National Academy Sciences of the United States of America,* 114: 926–931.

Kumari, G., S. K. Thakur, N. Kumar and B. Mishra. 2013. Long term effect of fertilizer, manure and lime on yield sustainability and soil or-ganic carbon status

under maize (Zea mays)–wheat (*Triticum aestivum*) cropping system in Alfisols. *Indian Journal of Agronomy*, *58*(2):152-158.

Kuzyakov, Y. and E. Blagodatskaya. 2015. Microbial hotspots and hot moments in soil: concept and review. *Soil Biology and Biochemistry*, *83*: 184-199.

Li, F., L. Chen, J. Zhang, J. Yin and S. Huang. 2017. Bacterial community structure after long-term organic and inorganic fertilization reveals important associations between soil nutrients and specific taxa involved in nutrient transformations. *Frontiers in Microbiol,* 8: 187. 10.3389/fmicb.2017.00187.

Loyon, L. 2017. Overview of manure treatment in France. *Waste management*, *61*: pp.516-520.

Ma, D., L. Yin, W. Ju, X. Li, X. Liu, X. Deng and S. Wang. 2021. Meta-analysis of green manure effects on soil properties and crop yield in northern China. *Field Crops Research*, *266*: 108146.

Mazid, M. and T. A. Khan. 2015. Future of bio-fertilizers in Indian agriculture: an overview. *International Journal of Agricultural and Food Research*, *3*(3).

Möller, K. and T. Müller. 2012. Effects of anaerobic digestion on digestate nutrient availability and crop growth: A review. *Engineering in Life Sciences*, *12*(3): 242-257.

Pagliari, P.H. and C. A. Laboski. 2012. Investigation of the inorganic and organic phosphorus forms in animal manure. *Journal of environmental quality*, *41*(3): pp.901-910.

Parihar, S. S., K. P. S. Saini, G. P. Lakhani, A. Jain, B. Roy, S. Ghosh and B. Aharwal. 2019. Livestock waste management: A review.*Journal of Entomology and Zoology Studies*, *7*: 384-393.

Park, J. H., D. Lamb, P. Paneerselvam, G. Choppala, N. Bolan and J. W. Chung. 2011. Role of organic amendments on enhanced bioremediation of heavy metal (loid) contaminated soils. *Journal of hazardous materials*, *185*(2-3): 549-574.

Rayne, N. and L. Aula. 2020. Livestock manure and the impacts on soil health: A review. *Soil Systems*, *4*(4): p.64.

Riley, H., R. Pommeresche, R. Eltun, S. Hansen and A. Korsaeth. 2008. Soil structure, organic matter and earthworm activity in a comparison of cropping systems with contrasting tillage, rotations, fertilizer levels and manure use. *Agriculture, ecosystems and environment*, *124*(3-4): 275-284.

Shanka, D. 2020. Roles of eco-friendly low input technologies in crop production in sub-Saharan Africa. *Cogent Food and Agriculture*, *6*(1): 1843882.

Sharratt, B. S., A. McGuire and D. Horneck. 2018. Early-Season Wind Erosion Influenced by Soil-Incorporated Green Manure in the Pacific Northwest. *Soil Science Society of America Journal*, *82*(3): 678-684.

Song, W. and M. Guo. 2014. Residual veterinary pharmaceuticals in animal manures and their environmental behaviors in soils. In *Applied manure and nutrient chemistry for sustainable agriculture and environment* (pp. 23-52). Springer, Dordrecht.

Sun, R., X. X. Zhang, X. Guo, D. Wang and H. Chu. 2015. Bacterial diversity in soils subjected to long-term chemical fertilization can be more stably maintained with the addition of livestock manure than wheat straw. *Soil Biology and Biochemistry,* 88: 9–18.

Thiessen Martens, J. and M. Entz. 2011. Integrating green manure and grazing systems: A review. *Canadian Journal of Plant Science*, *91*(5): 811-824.

Thomas, C.L., G.E. Acquah, A. P. Whitmore, S. P. McGrath and S. M. Haefele. 2019. The effect of different organic fertilizers on yield and soil and crop nutrient concentrations. *Agronomy*, *9*(12): p.776.

Thompsin, P. 1968. Methods for disposal of poultry manure.

Tilman, D. and M. Clark. 2015. Food, agriculture and the environment: Can we feed the world and save the earth?. *Daedalus*, *144*(4): 8-23.

Valadares, R. V., L. D. Ávila-Silva, R. D. S. Teixeira, R. D. Sousa and L. Vergütz. 2016. Green manures and crop residues as source of nutrients in tropical environment. *Larramendy, ML; Soloneski, S. Organic fertilizers: From basic concets to applied outcomes. IntechOpen*, 51-84.

Wang, Y.D., N. Hu, T. D. Ge, Y. Kuzyakov, Z. L. Wang, Z. F. Li, Z. Tang, Y. Chen, C. Y. Wu, Y. L. Lou. 2017. Soil aggregation regulates distributions of carbon, 616 microbial community and enzyme activities after 23-year manure amendment. *Applied Soil Ecology,* 111: 65–72.

Watson, C. A., D. Atkinson, P. Gosling, L. R. Jackson and F. W. Rayns. 2002. Managing soil fertility in organic farming systems. *Soil use and management*, *18*:

239-247.

Watson, C. A., I. Öborn, A. C. Edwards, A. Dahlin, S. Eriksson, J. Lindström, B. E. M and R. L. Walker. 2012. Using soil and plant properties and farm management practices to improve the micronutrient composition of food and feed. *Journal of Geochemical Exploration*, *121*: 15-24.

Xu, Z., G. Li, N. Huda, B. Zhang, M. Wang and W. Luo. 2020. Effects of moisture and carbon/nitrogen ratio on gaseous emissions and maturity during direct composting of cornstalks used for filtration of anaerobically digested manure centrate. *Bioresource Technology*, *298*: p.122503.

Yang, L., J. Bai, J. Liu, N. Zeng and W. Cao. 2018. Green manuring effect on changes of soil nitrogen fractions, maize growth, and nutrient uptake. *Agronomy*, *8*(11): 261.

Ye, G., Y. Lin, D. Liu, Z. Chen, J. Luo, N. Bolan and W. Ding. 2019. Long-term application of manure over plant residues mitigates acidification, builds soil organic carbon and shifts prokaryotic diversity in acidic Ultisols. *Applied Soil Ecology*, *133*: 24-33.

Zhang, Q., W. Zhou, G. Liang, X. Wang, J. Sun, P. He and L. Li. 2015. Effects of different organic manures on the biochemical and microbial characteristics of albic paddy soil in a short-term experiment. *PLoS ONE,* 10:e0124096.

CONFLICT OF INTEREST

The authors have not declared any conflict of interests.

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