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# Effect of animal manure application on sustainable potato production and soil structure management

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**Abstract**
Historically animal manure has been the most valuable and accessible source of plant nutrients across the globe. Potato is worldwide important food, feed and industrial crop with the highest provision of calories, vitamins and nutrients compared to other crops. The aim of the review is therefore to assess the current state of knowledge about the effects of the use of animal manure on sustainable potato production and soil structure. It also briefly discusses the results of research on the benefits of animal manure on the physical properties of soil and the general management of soil health. The overview of sustainable crop production, types and profiles of animal manure, their benefits on the soil structure enhancement and potato yield increment have been briefly reviewed. Many literatures have narrated that animal manure could boost the productivity and yield of potato in the different parts of the world either solely or in combination with inorganic fertilizers. Similarly, facts have been unfolded about the merits of animal manure on the improvement of soil physical properties which in turn improves the agronomic and ecological services of the soil. Misuses of animal manure can lead to possible contamination of the water bodies and the atmosphere. It has been suggested that the application of manure at the right time right dose, either solely or in combination with inorganic fertilizers, are thought to alleviate related challenges while sustaining potato production.

**Keywords:** animal manure, sustainable crop production, potato, soil structure

## Introduction
The world potato production in 2019 was 423 MT, and potatoes can nourish higher calories, vitamins and nutrients per unit area of land sown than other stable crops. Due to its multiple usage in the food, feed and industrial inputs, it is a plant of a great economic importance globally (FAOSTAT, 2019) [13]. Mixed crop-livestock systems have merits over crop enterprise alone. According to Entz and Martens (2009) [11] integrated crop-livestock systems have the potential to maintain and boost soil fertility levels. Similarly, organic C and soil N were increased, and leachable N decreased under the integrated crop-livestock enterprise compared to sole crop enterprise as reviewed by (Kumar *et al*., 2019) [23]. As a result, the inclusion of livestock in crop schemes has improved overall crop yields and economic profits (Kumar *et al*., 2019) [23]. For decades, animal manure has been recognized as the ultimate source for the soil nutrients, with a contribution scale up to about 37-61% of total nitrogen input to the land surface (Bouwman *et al*., 2013) [5]. Predictions are that demand for the animal population will increase as a result of an increase in the human population and changes in dietary structure, so that as meat consumption increases in the coming decades, nitrogen production from animal manure will increase (Herrero and Thornton, 2013) [18]. Potatoes area generally one of the important foods, feed and industrial crops. Soil organic matter levels and their biological activity is one of the most important and decisive factors in ensuring and maintaining high yield potential in the world's potato production system (FAO, 2009) [12]. The aim of the review is therefore to assess the current state of knowledge about the effects of the use of animal manure on sustainable potato production and soil structure. It also briefly discusses the results of research on the benefits of animal manure on the physical properties of soil and the general management of soil health.

**Overview of sustainable crop production:** Agricultural productivity has been increased and food security was also achieved via the green revolution interventions.

However, through time it was evident that the green revolution eventually led to top soil deterioration, pollution of ground water, production cost increment and decline of the organic farms (Pimentel *et al*., 2005) [32]. On top of that, it is predicted that the world population will shoot to 8.9 billion by the 2050 and demand for agricultural products, especially food will reach climax (Lichtfouse *et al*., 2009) [26]. This ignites the need for twofold crop yields compare to the present by applying sustainable crop production means. The central focus of sustainable crop production is to enhance soil organic matter content and reduce soil erosion via various management options (Doran, 2002) [10].

Soil organic matter management, lowering of chemical pesticide application, safeguarding of biodiversity, integrated pest management, ameliorating nutrient quality, ensuring food health and quality and eventually boosting the profitability of the crop sector are the most pillar principles of sustainable crop production; and this secures the share of the upcoming generations without polluting the environment (Imadi *et al*., 2016) [20]. In line with 2009 FAO's report the level of soil organic matter and its biological activity is one of the most vital and decisive factors for ensuring and maintaining high yielding potential in global potato production system (FAO, 2009) [12]. A similar report had appreciated the importance of animal manure as organic fertilizer for sustainable potato production not only by increasing its yield, but also improving the efficiency of chemical fertilizers; and it is realized that potato is the best responsive of all other crops to animal manure application. The 21 years long study has revealed that organic plots have shown a higher biodiversity and could boost soil fertility than conventional plots (Fig 1).

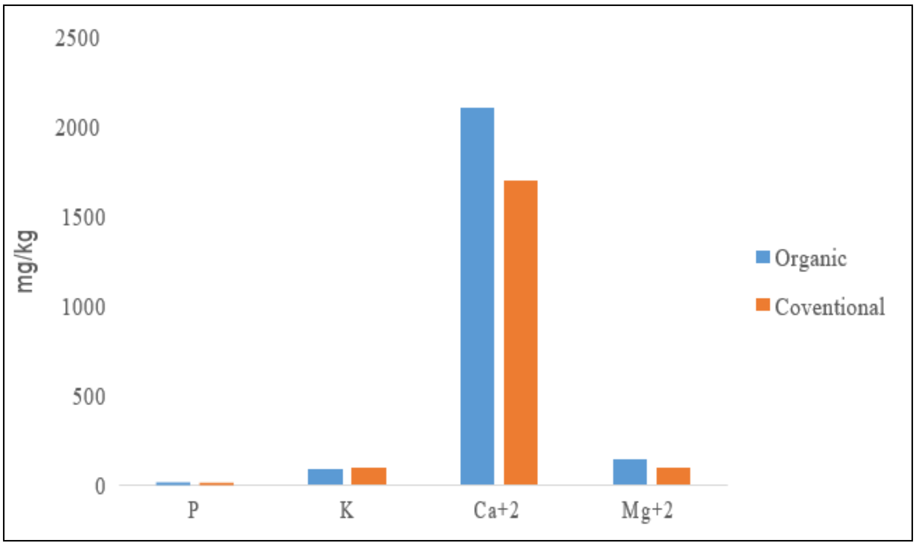


**Fig 1:** Mean values of selected soil minerals from organic and conventional farm of potato studied for 21 years (Mader *et al*., 2002) [29].

## Organic farming

In a broader sense organic farming utilizes various eco-friendly pest control methods and huge amount of animal and plant based organic fertilizers, and nitrogen fixing cover /green crops. It uses fewer chemical inputs (fertilizer and pesticide), while reducing soil erosion and nitrate leaching into the water bodies, eventually recycles animal waste back into the farm (Admachak, 2008) [1].

## Types of animal manure and their nutrient profiles

Soil productivity can be sustainably ameliorated by the important source of plant nutrients so- called animal manure. The inherent characteristics animal manure can be varied based on animal species, ages of animal, nutrition, protein and fiber content, digestibility of the diet, environment, housing and time of production (Lorimor *et al* ., 2004) [27]. In a general term, many scholars have agreed that cattle, poultry and pig manures are the most stable organic fertilizers after being applied to the soil respectively (Dendooven *et al*., 1998; Kirchman and Bernal, 1997) [22]. Pulleman *et al*. (2003) [33] have found that increments in total soil organic matter (SOM), earthworm activity, water stable macro-aggregation, and N mineralization in field where manure was used as compared with conventional field. The properties of this soil are the most important indicator of soil quality. The basic philosophy, in which all organic certification bodies operate, is to create and maintain underlying soil fertility through the use of biological processes, rather than importing short-term fertility in the form of soluble mineral fertilizers and pesticides, such as conventional agriculture (Derfa, 2002).

**Table 1:** Total nutrient contents of various livestock manures based on their fresh weight

| Manure type | Contents | | | | | |
|---|---|---|---|---|---|---|
| | Dry matter (%) | Nitrogen N | Phosphate P2 O5 | Potash K2O | Sulfur SO3 | Magnesium MgO |
| | | Kg/t- Solid manure | | | | |
| Cattle | 25 | 6.0 | 3.5 | 8.0 | 1.8 | 0.7 |
| Pig | 25 | 7.0 | 7.0 | 5.0 | 1.8 | 0.7 |
| Sheep | 25 | 6.0 | 2.0 | 3.0 | ND | ND |
| Duck | 25 | 6.5 | 5.5 | 7.5 | 2.7 | 1.2 |
| Layer | 30 | 16 | 13 | 9.0 | 3.8 | 2.2. |
| Broiler | 60 | 30 | 25 | 18 | 8.3 | 4.2 |
| Kg/m3 – Liquid manure | | | | | | |
| Dairy | 6 | 2.8 | 1.3 | 3.5 | 0.8 | 0.7 |
| Beef | 6 | 2.3 | 1.3 | 2.7 | 0.8 | 0.7 |
| Pig | 4 | 4 | 2 | 2.5 | 0.7 | 0.4 |

(Adapted from Chambers *et al*., 2001) [6].

Yield responses to the addition of S fertilizer are increasingly common in raped seed and grains in soil types that are deficient in Sulfur (S), generally sandy and shallow soils are with low S deposition. The animal manure provides a useful amount of S and magnesium (Mg) (Table 1). Soil bioactivity can be stimulated by adding manure, which can increase the number of worms in some soils. Such improvements in the physical and biological fertility of the soil are more likely to be achieved with regular application of animal manure (Chambers *et al*., 2001) [6].

**Benefits of sustainable potato production using animal manure**

Previously, animal manure was an important source of plant nutrients. Its value in maintaining and improving soil productivity has been known since ancient times (Nowak *et al*., 1998) [31]. Fertilizing crops with nutrients for cattle dung began several millennia ago and is mentioned in the Old Testament Bible and other ancient documents. Recent Michigan studies have shown that applying poultry manure with a low dose of fertilizer can increase potato tuber yields by 30 to 60 cwt per hectare in some places (Snape *et al*., 2003) [35]. The key indicators for sustainable potato production are biodiversity and diversity, seed and seed quality, soil health and fertility management, nutrient supply and nutrient imbalance, soil protection, pest and water management, post-harvest management value creation and marketing farmers' health, safety and well-being (Lutaladio *et al*., 2009) [28].

**Table 2:** Mean yield of potato under the animal manure and NPSZnB fertilizer application in Awi Zone, Ethiopia, 2017.

| NPSZnB (kg/ha) | Animal manure (t/ha) | Yields (t/ha) | | |
|---|---|---|---|---|
| | | Marketable yield | Total yield | Total dry biomass yield |
| 0 | 0 | 15.3 | 18.5 | 122.8 |
| 65.7 | 10 | 18.7 | 23.9 | 147.4 |
| 133 | 20 | 20.5 | 24.6 | 155 |
| 199 | 30 | 22.7 | 26.2 | 161.7 |

(Data adapted from Bewket *et al*., 2018)

This research has shown the importance of animal manure in the boosting potato yield. Furthermore, it explicitly depicts NPSZnB fertilizer in combination with animal manure results in high yield and better performance of yield components than applying alone (Bewket *et al*., 2018) [4]. Application of cattle manure from zero to 30 t ha-1 had also resulted in statistically significant incremental effect in average tuber weight, marketable and total tuber yield and total dry biomass yield (Table 2). Similarly, the application of 20 to 30 t ha -1 FYM + 66.6% of the recommended chemical NP fertilizers provide higher total tuber yield as compared to the full dose of NP fertilizers without FYM in vertisol (Balemi, 2012) [2]. Therefore, it can be advised that this research output can benefit farmers, researchers, investors and others considering the agro-ecological requirement of the crop.

**Effects of animal manure on soil structure**

Soil physical properties include characteristics related to particle size distribution, particle arrangement (structure), volume and porosity, density, hydraulic conductivity, water holding capacity, soil temperature, soil air and erodibility. The main processes strongly influence ecological, pedological and agronomic processes at the soil, landscape and watershed scale, with consequences for ecosystem services and ecological processes (Fig 2) and soil organic matter and its dynamics (Reynolds *et al*., 2002) [34]. Among the main ecological processes, the physical properties of soil determines gas flow, elemental circulation, biodiversity, net primary productivity (NPP). Similarly, soil formation, humification, illuviation, horizonazation and transformations, and rate of leaching are examples of soil processes that are affected by the physical properties of the soil (Fig 2). Therefore, the physical properties of soil affect agricultural yield and productivity. Adaptation to climate change, seasonal change, and the parameters that affect it is mediated by the physical properties of the soil and related processes (Fig 2). Changes in soil properties, in turn, affect the content of organic matter (SOM) in the soil and its cycle. For example, SOMs affect soil properties (structure, porosity, density, hydraulic conductivity, water retention capacity, thermal conductivity etc) (Fig 2) that affect the basin and dynamics of SOMs. The content of SOM and its quality affect the physical properties and processes of the soil (Fig 2). SOM content is an important indicator of soil quality that strongly influences the formation and stabilization of soil aggregates (Franzluebbers, 2002) [15].

Walsh *et al*. (2012) [38] have pointed out the organic soil plays an important and multifaceted role in the earth. Physically, organic soil affects the structure of the soil and all its related properties while chemically, the organic matter of the soil affects its ability to catalyze exchange and its ability to inhibit changes in the soil pH (Walsh *et al*., 2012) [38]. Biological, organic matter is present in most plants acts as microbial biomass and nutrient and energy supply (Fig 2). Soils that are biologically and chemically fertile but not physically conducive to crop growth do not meet their agricultural potential (Fig 2). Soil productivity is determined by the combination of the influence of organic matter on physical, chemical and biological properties of soil (Walsh *et al*., 2012) [38].

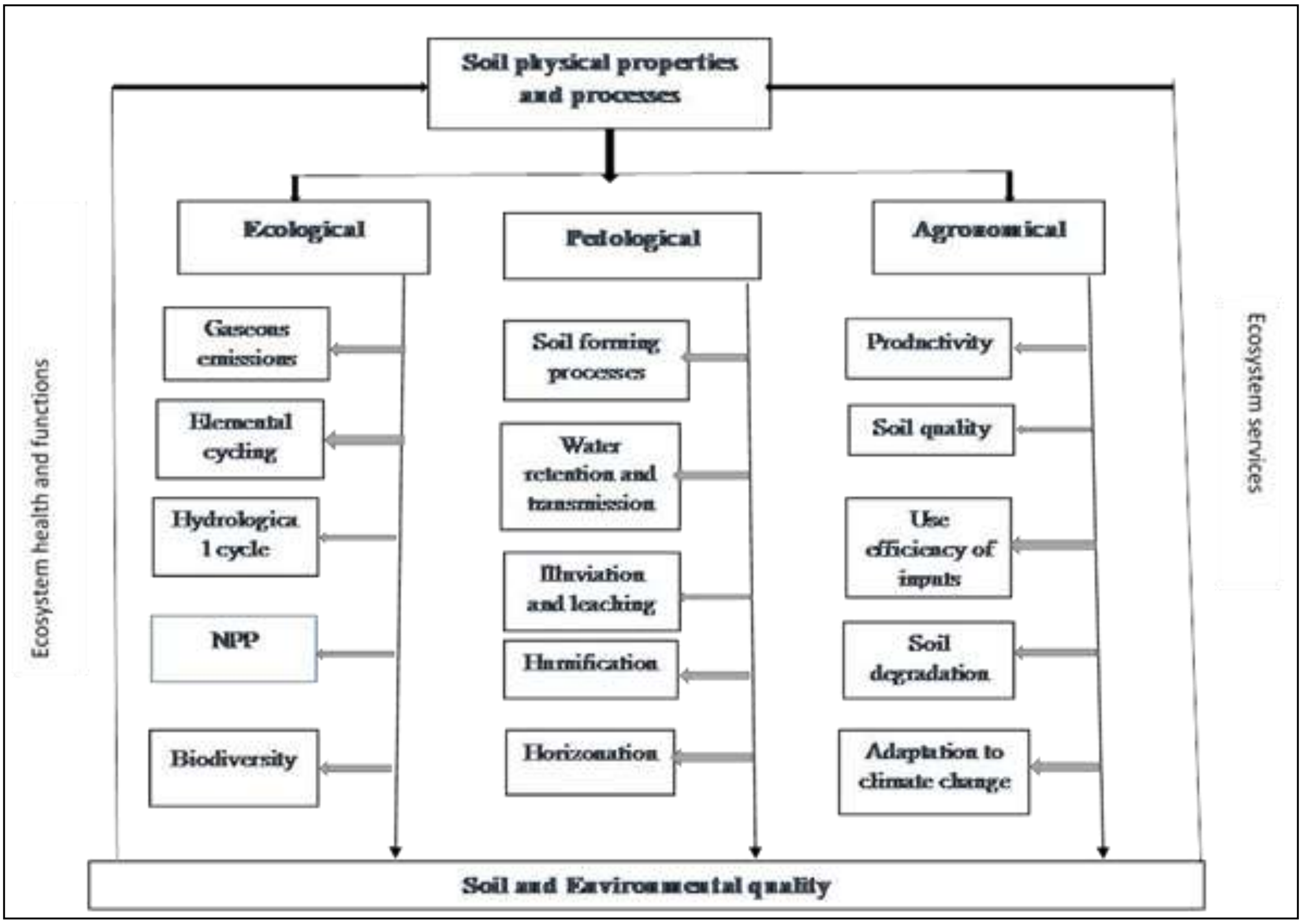


**Fig 2:** Schematic representation of ecological, pedological and agronomical impacts of soil physical properties and process as conditioned by soil organic matter as adapted from (Lal, 2011) [24].

**Challenges associated with animal manure**

The excessive use of fertilizes can result in the distribution and leaching of N and other nutrients, leading to contamination of surface and groundwater. If the crop is based on N requirements, the use of animal manure can be a major cause of excess P, as animal manure usually contains a smaller amount of N compared to P to meet crop needs (Toth *et al*., 2006). Adjusting the rate of application so that the manure provides sufficient P reduced the risk of P outflow from the field (Toth *et al*., 2006). However, it is also more likely to not meet the nitrogen requirements of the crop. Some excess nitrogen can accumulate in nitrogen reservoirs in the soil. Nitric oxide (N2O) from manure accounts for 44% of the total anthropogenic emissions of N2O, the largest anthropogenic stratospheric ozone-depleting substance and the third most important anthropogenic greenhouse gas (Tian *et al*., 2016) [37]. Excess nitrogen and phosphorus stimulate eutrophication of inland waters (Conley *et al*., 2009) [7] and are transported far from their original sources, degrading coastal water quality and even hypoxia (Yang *et al*., 2016) [38]. Manure production is more than 66% of NH3 emissions from the agricultural systems (Beusen *et al*., 2008) [3]. Thus, an increase in manure production may lead to an increase in NH3 emissions which harms public health and the environment (Sutton *et al*., 2013) [36]. The remaining excess nitrogen can zoom out of the soil profile and contaminate groundwater in the form of nitrates (Ju *et al*., 2006) [21]. It has been suggested that animal manure was the most important source of anthropogenic N 2O emissions in the 2000s (Davidson and Kanter, 2014) [8]. In some farms weed infestation would be a problem when not well decomposed animal manure is used as an organic fertilizer (Miller *et al*., 2015) [30].

**Conclusion and future prospects**

Historically animal manure has been the most valuable and accessible source of plant nutrients across the globe. Briefly discussed the results of research on the benefits of animal manure on the physical properties of soil and the general management of soil health. The overview of sustainable crop production, types and profiles of animal manure, their benefits of on the soil structure enhancement and potato yield increment has been reviewed. Many literatures have narrated that animal manure could boost the productivity and yield of potato in the different parts of the world either solely or in a combination with inorganic fertilizers. Similarly, facts have been unfolded about the merits of animal manure on the improvement of soil physical properties which in turn improves the agronomic and ecological services of the soil. Misuses of animal manure can lead to possible contamination of the water bodies and the atmosphere. It is suggested that application animal manure to potato at the right time and right dose either solely or in combination of the inorganic fertilizers are believed to lessen the associated challenges while sustaining potato production.

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**References**

1. Admachak R. Britannica. Retrieved November 02, 2020 2008, from https://britannica.com/topic/organic-farming

2. Balemi T. Effect of integrated use of cattle manure and inorganic fertilizers on tuber yield of potato in Ethiopia. Journal of soil science and plant nutrition 2012;12(2):257-265. Retrieved from http://dx.doi.org/10.4067/S0718-95162012000200005
3. Beusen A, Bouwman A, Heuberher P, Van Drecht G, Van Hoek K. Bottom-up uncertianty estimates of global ammonia emissions from global agricultural production systems. Atmons. Environ 2008;42:6067-6077.
4. Bewket GB, Derbew B, Tesfaye A. NPSZnB fertilizer and cattle manure effect on potato (*Solanum tuberosum* L.) yield and yield componenets in Awi Zone, Ethiopia. International journal of Soil Science 2018;13:35-41.
5. Bouwman L, Goldewijk K, Van Der Hoek K, Beusen A, Van Vuuren D, Willems J, *et al*. Exploring global changes in nitrogen and phosphorus cycles in agriculture induced by livestock production over the 1900-2020 period. P. Natl. Acad. Sci. USA 2013;110:20882-21195.
6. Chambers B, Nicholson N, Smith K. Managing Livestock Manures. Meden Vale, Mansfield : Silose Research Institute 2001.
7. Conley D, Paerl H, Howarth R, Boesch D, Seitzinger S, Haevens K, *et al*. Controlling eutrophification: nitrogen and phosphorus Science 2009;323:1014-1015.
8. Davidson E, Kanter D. inventories and scenarios of nitrous oxide emissions. Environ. Res. Lett 2014. Retrieved from https:doi.org/10.1088/1748-9326/9/10/105012. Defra. Understanding soil fertility in organically farmed soils. Defra 2002.
9. Dendooven L, Bonhomme E, Merckx R. N dynamics and sources of N2O production following pig slurry application to a loamy soil. Biol Fertil Soils 1998;26:224-228. Retrieved from https://doi.org/10.1007/s003740050371
10. Doran J. Soil health and global sustainability. Translating science into practice. Agric. Ecosyst. Environ 2002;88:119-127.
11. Entz M, Matens T. Organic cro-livestock systems. In C. Francis (Ed), Organic Farming: The Ecological System. Agron Monogr 2009, 5469-84.
12. FAO. Food and Agricultre Ogranization of the United Nations. Retrieved November 02, 2020, from 2009. http://www.fao.org/3/a-i1127e.pdf
13. FAOSTAT. Food and Agricultural Oranization. Retrieved Novemebr 6, 2020 2019, from https://www.statista.com/statistics/192966/us-potato-production-since-2000/
14. Finckh M, Schulte-Geldermann E, Bruns C. Challenges to organic potato farming: disease and nutrient management. Potato Res 2006;49:27-42. doi:doi:10.1007/s11540-006-9004-3
15. Franzluebbers A. Water inflitration and soil structure related to organic matter its stratification with depth. Soil and Tillage Research 2002;66:197-205.
16. Gold M. What is Sustainable Agriculture? United States Department of Agriculture, Alternative Farming Systems Information Cneter. National Agriculture Library, MD 2009, 20705-2351.
17. Gomiero T, Pimentel D, Paoletti M. Environmental impact of different agriculture management practices: Conventiola vs. organic. Critical Reviews in Plant Sciences 2011;30:95-124.
18. Herrero M, Thornton P. Livestock and global change: emerging issues for sustainable food systems. P. Natl. Acad. Sci. USA 2013;110:20878-20881.
19. IFOAM. Definition of Organic Agricultre. Retrieved November 03, 2020 2010, from http://www.ifoam.org
20. Imadi S, Shazadi K, Gul A, Hakeem K. Sustainable crop production system. Springer. Retrieved 2016**.** from https://doi.org/10.1007/978-3-319-27455-3 6
21. Ju X, Kou C, Zhang F, Christie P. Nitrogen balance and groundwater nitrate contaminatio: Comparison among three intensive cropping systems on the North China Plain. Eniron. Pollut 2006;143:117-125.
22. Kirchman H, Bernal M. Organic waste treatment and C stablization efficiency. Soil Biology and Soilchemistry 1997;29(11-12):1747-1753.
23. Kumar S, Sieverding H, Lai L, Thandiwe N, Wienhold B, Redfearn D, *et al*. Facilitating crop-livestock reintegration in the North Great Plains. Agronomy Journal 2019;111:2141-2156. Retrieved from https://doi.org/10.2134/agroj2018.070441
24. Lal R. Organic matter, effects on soil physical properties and processes. In : Glinski J.; Horabik J.; Lipiec J.(eds) Encyclopedia of Agrophysics. Encyclopedia of Earth Sciences Series. Springer, Dodhrecht 2011. doi:https://doi.org/10.1007/978-90-481-3585-1_102
25. Lampkin N. Organic Farming. Ipswich 1990.
26. Lichtfouse F, Navarrete M, Debaeke P, Souchere V, Alberola C, Menassieu J. Agronomy for sustainable agriculture. R review. Sustain. Dev 2009;29:1-6.
27. Lorimor J, Wendy P, Sutton A. Manure Characterstics. Iowa: Iowa State University 2004.
28. Lutaladio N, Ortiz O, Haverkort A, Caldiz D. Sustainable potato production. Guidelines for developing countries. Rome : FAO 2009.
29. Mader P, Fliebach A, Dubois D, Gunst P, Fried P, Niggli U. Soil fertility and biodiversity in organic farming. Science 2002;296:1694-1697.
30. Miller Z, Menalled F, Sainju M, Lenssen A, Hatfield P. Intergrating sheep grazing into cereal-based crp rotations: Spring wheat yields and weed communitiies. Agronomy Journal 2015;107:104-112. Retrieved from https://doi.org/10.2134/agronj14.0086
31. Nowak D, McHale P, Ibarra M, Stevens J, luley C. Modeling the effects of urban vegetation air pollution. In: Gryning SE, Chaumerliac N (EDs.), Air pollution modeling and its application XII. Plenumpress, New York 1998, 399-407. Retrieved Nov 07, 2020, from https://www.researchgate.net/pulication/222411712 Air Pollution Removal by Urban Trees and Shurbs in the United States
32. Pimentel D, Hanson P, Douds D, Seidel R. Enironmentsl, energetic, and economic comparisons of organic and conventional farming systems. Bioscience 2005;55:573-582.
33. Pulleman M, Jongmans A, Marinissen J, Bouma J. Effects of organic versus conventional arable farming on soil structure and organic matter dynamics in a marine loam in the Netherlands. Soil Use and Management 2003;19:157-165.
34. Reynolds W, Bowman B, Drury C, Tan C, Lu X. Indicators of good soil physical quality: density and storage parameters . Geoderma 2002;110:131-146.
35. Snapp J, Nyiraneza M, Otto M, Kirk W. Managing manure in potato and vegetable systems. Extension Bulletin E 2003, 2893.
36. Sutton M, Reis S, Riddick S, Dragosits U, Nemitz E, Theobald M, *et al.* Towards a climate-dependent paradigm

of ammonia emission and deposition. Philos. T.R. Soc. Lond. B 2013, 368. Retrieved from https://doi.org/10.1098/rstb.2013.0166

37. Tian H, Lu C, Ciais P, Michalak A, Canadell J, Saikawa E. The terrestrial biosphere as a net source of greenhouse gases to the atmosphere. Nature 2016;531:225-228.
38. Walsh E, Kevin P, McDonnel. The influence of added organic matter on soil physical, chemical, and biological properties: a small-scale and short-time experiment using straw. Archives of Agronomy and Soil Science 2012;58:201-205. doi:DOI:10.1080/03650340.2012.697999
39. Yang Q, Tian H, Li X, Ren W, Zhang B, Zhang X *et al*. Spatiotemporal patterns of livestock manure nutrient production in the conterminous United States from 1930 to 2012. Total Environ 2016;541:1592-1602.