Review Article

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Agronomic and Ecosystem Services Potentialities of Green Manure Utilization

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ABSTRACT

Anthropic actions are always very harmful to environment as long as the industrial peoples and farmers are interested to use chemical products and natural resources excessively to meet their needs. However, recently, an ecological approach based on the use of green manure can be adopted as sustainable development approach of agriculture in the world. This study focused to analyze agronomic and ecosystem services potentialities made by green manure use of to explore its various functions. Different authors indicated that green manure plants have various potentialities namely economic services, ecological services, positive effects on plant health and quality and quantity of yield, carbon sequestration, improvement of soil health and biodiversity, landscape services, and mitigation of soil water losses, air pollution and environment degradation. Because of a few economic profits comparatively to those from the use of excessive agrochemical products, the ecological compensation mechanism is the main way to promote farmers to plant green manure for sustainability of agriculture.

Introduction

The global impact of climate change caused by the excessive use of natural resources and the over growth of world population harms biodiversity species and disturbs ecosystem functions. It was identified that land degradation, one of many consequences of poor management. (Holden, S., Shiferaw, B., & Pender, J., 2005) [1] of natural capital (soil, water, and biodiversity such as vegetal and animal organisms) is the problem of worldwide caused anthropological manipulation of land, which altered chemical, physical and biological soil properties (Lal, R, 2001). The Global Assessment of Human-Induced Soil Degradation project (GLASOD) in 1988 estimated 1,964 million (nearly 2 billion) hectares degraded worldwide and more than 22% of combined agricultural land pasture and woodland were destroyed by human-induced soil degradation (Chen H. J. et al. 2014). This problem of land degradation evolved the climate change, biodiversity, food security, quality of water and air. The resource land is characterized by a complex structure of two interlocking systems: a system of natural resources ecosystems and human society. The interaction between them determines how natural resources are managed (Temengsgen G et al. 2014). For example, the findings of Lingling Hou (2012) [2] estimated that 50% of the land in China was degraded and more than 466 million hectares have been affected. That situation caused environmental and ecological damages [2].

However, overuses of agrochemical products [3] were fundamental causes of soil degradation in the worldwide. It would like to cite chemical fertilizers and pesticides. The agricultural industry is ranked first for the consumption of pesticides with 1.84 Mt in 2014 and non-biological pesticides account for

91.78% in China [4]. Many researchers stated that green manure is useful to limit those negative effects of using of artificial products in agriculture. The world community would undertake maintaining soil fertility and biodiversity in order to assume the equilibrium between food supplies, the population growth and safe environment [5]. To reach this objective, many governments have undertaken different measures for conservation and sustainable use of biological diversity [6]. Operationally, many farmers must use green manure to limit the excessive application of chemical products in agriculture. The objective of this review is to give the answers to this big question: How green manure practices could perform farming production and environment damage?.

The environment scientists tried to complete the commitment of the States in implementing the convention on Biological Diversity universally acknowledged in 1992 by discovering that the use of green manure could be one of the solutions of land degradation, agricultural products quality and environment damage. This is why this review paper tried to give different explanations and details about various agricultural performances and ecosystems services provided by green manure. By definition, green manure is produced by ploughing leaves and roots of green plants at maturity into the soil. After a while, they become compost or green fertilizer [7]. According to some writers, green manures are the material of plant-incorporated into the field [7,8] and for others green manure is plants used to produce compost or green fertilizer [5]. That big question of research has been answered through reviewing numerous publications based on the benefits of using green manure. Methodologically, this review summarizes and discusses the finding from the following principal publications reviewed below: (Table 1).

Table 1.

Authors and Year of publication	Ecosystem functions of green manures	Title	Journal of publication
Adrian, J. P. (1927) [5]	Ecological services (Maintain soil biodiversity and fertility)	Green manuring principles and practice	The Wiley Agricultural series. John Wiley and sons, Inc.: New York, USA
(Ntakirutimana L. et al. (2019) [9]	Economics services (Increase yields, reducing chemical fertilizers spends)	Green manure planting incentive measures of local authorities and farmers 'perceptions of the utilization of rotation fallow for sustainable agriculture in Guangxi	Sustainability journal of MDPI
Anbukkarasi, V. and Sadasakthi, A. (2016) [10]	Economic services (yield quality and high net profit)	Effect of leguminous green leaf manures and leaf extract on growth, yield, quality and economics of bhendi	Indian Journal of Agricultural Research
(Piraneque Gmbasica N. V. et al. (2018) [11]	Ecological services (carbon sequestration and soil organic matter)	Green manure: Alternative to carbon sequestration in the typic ustipsamment under semi-arid conditions	Spanish Journal of soil science

Use of Green Manure

According to Costanza Robert (1997) [12], the natural ecosystem services were defined as the benefits that the nature provided to humans through natural resources transformations into a low of essential goods and services [12]. In this way, green manure is used to fertilize degraded agricultural land and save biological diversity in the soil. To optimize the ecological and economic services value from green manure, farmers used diverse models of planting such as rotation fallowing, inter-cropping and double cropping. Those technologies improve ecosystem services, support agricultural production performance and safe environment.

The use of green manure contributes to maintain ecosystem systems and to give ecosystem services value to human interventions which aim to promote sustainable development. Green manuring increased the CO_2 concentrations and providing biological-Nitrogen in the soil [13,14], soil shade, soil organic matter (SOM) and soil organic carbon (SOC) when turned into the soil [14,15] as economic benefits [15], ecosystem services [7], and mitigation of pollution and beautify landscapes.

Green Manure Species

In the world, it is observed many kinds of green manure and cover crops those farmers use as green fertilizer in the fields for different reasons. However, the ryegrass (*Lolium perenne),* winter oilseeds (*Brassica napus ssp. oleifera var. biennis*), and winter rye (Secale cereale L.) were used in mixture to control the biomass and weeds and to increase crops yields in rotation crops [15]. In South Africa, according to the evaluation of green manure legumes have the potentiality to increase the crops yields in smallholder farms (Jude, J.O.O., 2011) [16]. It can be used in tropical region to increase the yield and agronomic performance of common beans [17]. Then, green manure plants play a significant role in farming systems management through its functions, such as the financial services, ecosystem/ecological services, and cultural landscape services functions [18] (Rovanovskaya A.A 2008).

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Economic Services Functions

The practice of green manuring reduces the biomass, the density of the weeds, and increases at maximum the crop yields and the green manure crops could improve the health of soil when it was turning into the ground after maturity [7,8]. Green manure practices bring economic benefits [9] through reducing the costs of inputs of the farmers, increase yields. It is not easy to capture all of these gaps of costs during the process of the market transaction [19] without adapted scientific methods. It is observed the indirect effects of green manure practices on the cost of disease damages management (McGuire, A., 2016). With the incorporation of different leaves of green manure (*Abelmoschus esculentus*) in Bhendi cropping systems, the crops growth parameters performed well and yield quality, as well as high net profit and benefit-cost ratio were observed [20]. The evaluation of economic services of green manure is very important when the research needs to understand the contribution of green manure in ecosystem system. It is used different potential applications to evaluate the ecosystems services values namely the Life Cycle Assessment (LCA), Contingent Valuation Method (CVM), Willingness -To -Pay (WTP) and Willingness-To-Accept (WTA), bio-economic model (Wang T. et al., 2018), and economic benefits analysis [21]. Currently, those techniques of assessment were applied in environmental impacts assessment (EIA) [20]. Referencing to the capacity of fixing nitrogen, the low-cost nitrogen, a bio-fertilizer, is provided by green manure. Those plants are good patterns of wetland rice cultivation [22].

Ecological Services

Green manure crops have the potentiality to maintain ecosystem systems [9]. Ecosystem systems provide a variety of essential services, including water, air, and health, livelihood, and well-being (Barvanera Patricia Sandras Quijas, Karp Daniel S. et al., 2016). In France, near Toulouse and Orleans, crucifer's species, grown in the form of green manure (catch crops) released a large amount of mineral nitrogen (N) for later commercial crops and legumes cropped as green manure plants decreased the leaching of nitrates in extraordinary ways. The same authors indicated that mixing crucifers and legumes in farming systems was an operational solution to obtain multiples ecosystem services from both catch crops for providing nitrate and legumes for providing nitrogen as green manure services [23]. Specifically, Azolla, a tiny aquatic fern, was used as green manure in flooded rice planting [24]. Then, green manure crops can regulate multiples environmental problems such as pest and diseases control [25], carbon sequestration [18,26]. It contributes to water filtration mitigation, climate control [26], and beautification of the living environment. However, green manure improves air purification and quality of agricultural products [27,28] because conventional farming systems are the sources of Green Houses Gases (GHG) emissions [26].

Plant Health Improvement

The weeds are unwanted plants that hosted pathogens (Rodgers V.L, Stinson K.A and Finzi A.C. 2008) and play a principal role in various ecosystems. Many of those weeds led to direct and indirect damages in farming ecosystems such as the losses of fertile agricultural lands, biodiversity, areas for grazing animals, and production of livestock, chocking of navigation and canals of irrigation and diminution of the availability of water in the rivers. However, green manuring, by adding carbon into the soil (Blumenthel, D. M. Jordan, N.R. and Russelle, M.P 2003), is one of the different sustainable farming systems which can successfully bring sustainable weed control for environmental, social, and economic benefits and wellbeing (Garnavel L and Natarajan S K 2014). Green manure /covers crops destroy weeds, which could theoretically act as causes of pathogen inoculum for crops and make returning accumulated nitrogen to the soil, reduced nitrogen leaching, avoid erosion, and improve soil structure [23]. In Pacific North-West of United States of America, the green manure (Cover crops, Mustard, Sudan grass, Lupine, and Marigold used as biological control and canola, Crambe, meadowfoam, Milkweed, seed meals organic amendment) reduced the nematode impact (*Meloidogyne chitwoodi*) on potatoes by 50-80%, provide nematode control comparable to fumigation and improve soil physical characteristics especially water infiltration and penetration of resources [29]. Then, green manure crops and cover crops, used as green manure, played a significant role in controlling diseases and nematodes, which harm cropping patterns.

Carbon Sequestration

Farming systems can be a source of dioxide of carbon (CO_2), and when it surpasses plant carbon fixation by photosynthesis, CO_2 contributes to climate variability. In 2002, Reicosky estimated that tillage of the soil led to carbon losses between 30% and 50 %. However, when farmers incorporated green manure crops into the soil, they captured CO_2 through the humification of soil organic matter (SOM) fractions after the mineralization process and the content of soil organic carbon (SOC) increased [11]. However, green manure displayed a significantly greater soil organic carbon (SOC) than the crops taken as a reference [30]. Thus, green manure crops and cover crops contain the potential capacity to sequestrate carbon and improve smallholder farmers resilience with minimum trade-offs [31]. Allowing a fallow period between two seasons of cropping can increase the soil organic carbon (SOC). Then, the SOC is an effective measurement to compensate for anthropogenic GHG emissions [11,32]. In this context, Yang (2014) found that green manuring is a management strategy for mitigating soil degradation, increasing nutrient levels (nitrogen, carbon, and other micro-elements [33]. The same study indicated that green manure legumes increased significantly in the long term, the total carbon (C) and nitrogen (N), and the formation of the stable aggregate portion of the water measuring from 2 to 5 mm in the soil. Specifically, the nitrogen is the element of nutrients supplied chiefly by green manuring, since nearly all the soil, turning under the crop-legumes increased the nitrogen associated with organic matter [5].

Quality and Quantity of Yield Improvement

Reducing-cost-technology (RCT) consisted of the soil non-tillage and decreasing nitrogen over-fertilizing doses with green manures before crop patterns. Those plants have high potential for restoration of soil fertility and enhancement of terrestrial crop production [34] and provided best profits compared with the other plants (Whitmore A. P. et al, 2000) [35], also contributed significantly to the nutritional demand of green manure legumes, thereby providing an agro-ecological and sustainable production [36]. The grazing of green manure, especially oat (Avena sativa), pea/oat (A. Sativa/Pisum sativum) contributed to improving the available nitrogen production in integrated crop-livestock systems [37]. This system of production of agriculture consisted of capturing ecological interactions among different systems of land-use, making agricultural ecosystems more proficient at cycling nourishment, preserved the natural resources and environment and improved the quality of the soil and enhanced biodiversity (Franzluebbers, A. J., 2007;) [26,38]. The green manure vetch (*Vicia villosa*) more affected the quality of biological maize (*Zea mays*) compared to that of fallow lands associated with organic fertilizers (phosphorus supplement) on in a field experiment of two years in central Italy [39]. The rotation of crops (Bullock, D.G., 1992) is one of the different modes of planting green manure that brings high yield of crops.

Mitigation of Soil Water Losses, Air Pollution, and Environmental Degradation

Green manuring is one of the ways of moisture conservation in the soil. Thus, the adoption of moisture conservation techniques, *in situ*, was increasing the moisture availability. However, the growth of green manure crops after cereal harvesting had reduced infiltration from rainfall during the autumn season in Lituany of an average between 19.4 % and 21.7 % (2003) and between 7.0 % and 8.3% (2004) such as clover produced more biomass (0.407 g/m2) with more nitrogen (7.35 g/m2) when clover incorporated into the soil and it increased nitrogen concentration.

Improvement Of Soil and Biodiversity's Health

The soil organic matter (SOM) plays a central role in the function of farms and particularly in biologic farming [40] (Morton A. C., 2008). Green manure contributes, transformed by ploughing into the soil, to improve the physical and chemical properties and plant growth (Hrishan Chandra, 2005), [41,42]. Then, depending on its potential to fixe biological nitrogen, green manure legumes are providing nutrients to crops in cropping systems [43], The soil organic matter content is the home of millions of microorganisms which brooked down by bacteria and makes nitrogen available to plants (Pieters A.J 1927) [44]. The retention of plant nutrients (carbon, nitrogen, zinc, etc.) from organic inputs depends on the microbial community under environmental conditions [45,46] and bio-chars [47]. By using green manure, nitrogenous compounds and carbons are transformed by soil microorganisms into elements absorbed by crops [5]. In the plants, roots absorbed more nourishment concentration than shoots [48].

Why it is Necessary to Plant Green Manure in Agricultural Land?

The green manure practices safeguarded biodiversity and provided ecosystem services to agricultural systems by transforming nitrogenous compounds and carbons into elements absorbed by the next crops (Thomas Oladeji Fabunmi et al 2012; Pieters A, J., 1927). In the study conducted by Zandvakili showed that the roots had higher concentrations of nourishments than shoots [36,48]. found that the use of native species of the Caatinga Biome could affect the nutritional demand of the Market of Garden Crops significantly, thus providing a form of agro-ecological and sustainable production. Consequently, soil fertility in organic matter is managed mainly by planting green manure. For example, China milk vetch (*Astragalus sinicus L.*) planted and mixed with chemical nitrogen fertilizer reduced the application of chemical fertilizer (Ma Yanqin and Huang Guiqin, 2019) and increased yield of rice by 28.7% in southern China (Qin, W. et al.2012) [49] and decreased seasonal methane (CH_4) flux in the mono-rice cultivation system [49]. When the application rate of milk vetch is increased, also, the yield and production of rice increased (Chang H. L., et al, 2010). The combined utilization of vegetable-green manure and phosphorus-enriched compost (P) can then be considered a reliable option for managing N and P fertility in the short and long term and maintaining plant needs [39]. Green manure and cover crops are well recognized in many systems of agriculture. The application of green manure in smallholdings provides multiples profits. Those benefits are nitrogen fixation, soil organic matter content, and weeds control, the management of disease and pests, and soil erosion control. It is a significant low-cost added-value to technological options that integrate the consideration of nature conservation and productivity of agriculture (Pratt, O.J., 2016).

Ecological Compensation is Needed to Support Planting Green Manure

Although green manuring is one of good practices for sustainable development of agriculture, the increased cost of production of

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green manure reduces the willingness of farmers to plant green manure. Another method to promote farmers to adopt green manure is ecological compensation [9]. The eco-compensation is an approach like a trade-off in which compensatory laws attribute different values of the benefits of ecosystem services or the damage of the loss of the natural environment. That compensatory act corresponding to those goods or services lost or gains by the environment. The compensatory law can be a mechanism to ensure the ecosystem services flow (restoration of resources, recreation, or conservation of nature) and maintaining the flow of natural capital on which depending on the economy. The eco-compensation policy aims to encourage people (He, K. et al. 2016) to participate in sustainable agriculture.

A study conducted in Spain showed that the eco-compensation practices in environmental impact assessment (EIA) is much fewer because of only 407 of 1302 records of decisions (RoDs) reviewed (31%) mention eco-compensation and only 117 of 1302 RoDs (9%) described the measures of compensation mechanism (Villaroya, A. and Puig, J., 2013. The Willingness-To-Accept (WTA) the eco-compensation standards for farmers of fallow winter wheat in Hengshui, Hebei province, was 0.00095$/hm^2 [50]. Many factors affected significantly and positively the willingness of farmers to reduce pesticides, namely the farmers' environmental concern, cognition of pesticide residues, the quality of agro-products interest, and controls of inputs. The study also noted that regulations and countermeasures and enhancing farmers' self-control were essential to guide farmers toward environmentally-friendly measures in agricultural production (Zhang L et al 2018). On the contrary, to initiate a Pigouvian-tax, tax paid by economic actors when their activities generate negative externalities implies to proceed of actors' Willingness-To-Pay (WTP) for the negative externalities from agriculture. A study carried out using a model of dynamic equilibrium to assess the effects of the welfare of subsidy estimated that the impact of Pigouvian-Tax on the intensity of financial support was negative (Yang, L. et al., 2018). The eco-compensation based on financial support could give added-value on the well-being of human, maintaining dynamic effects of ecosystems and nature conservation because the Pigouvian-tax alone cannot play a significant role to correct the most considerable externalities in the long-run (Dennis W. C. and Glenn C. L., 1980; Kohn, R. E., 1986) [51-55].

Conclusion

The use of green manure in agricultural fields brings various profits in terms of economic benefits and environmental safeguarding. However, green manure practices must be adopted as a new sustainable development approach of agriculture. The study reviewed various papers related to green manure benefits. It was observed that green manure technologies help farmers to various advantages namely economic benefits, carbon sequestration, nitrogen fixation, SOC content improvement, biodiversity safeguard, etc. Because of high ecosystems services values and few economic profits of farmers, an ecological compensation system could be adopted widely as a new sustainable development approach in farm systems.

Conflict of Interest

No conflict of interest with any institution/organization.

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