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REVIEW PAPER

Concepts, Principles, and Application of Biodynamic Farming: a Review

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Abstract
Biodynamic farming is an old but new alternative agriculture for sustainable development. However, it is not well understood and practiced. It is similar to organic farming but incorporates metaphysical ideas in treating soil and crop growth. The objective of this paper is to review and give brief highlights about the concepts, principles, and applications of biodynamic farming. To review about biodynamic farming, different literatures, research works, and practical works have been reviewed. Different search engines were used in search of documents using keywords like biodynamic agriculture, organic farming, sustainable development, ecology, soil quality, and health. Biodynamic farming is regarded as "above and beyond organic." It was the first systematic method of organic farming as an alternative to the rise of high-input industrial agriculture. Biodynamic farming is the concern and practice of more than 5500 farmers globally, and the farming method has a very good preference among consumers of organic product. The number of countries with Demeter-International certified biodynamic activity increased from 42 to 55 with Germany having the largest (1552) biodynamic farms. Some of the principles of biodynamic farming are restoring the soil through the incorporation of organic matter; treating soil as a living system; creating a system that brings all factors that maintain life into balance; encouraging the use and significance of green manure, crop rotation, and cover crops; and treating manure and compost in a biodynamic way. Biodynamic farming is more than just a set of techniques; it is also a conceptual philosophy that applies to the farm's general structure. The foundation of biodynamics is the construction of a farm that functions holistically as an unbroken organism. Scientifically proofed, biodynamic farming has its own contribution to agriculture sustainability via effect on soil quality and improvement of quantity and nutritional quality of a produce and pest management. Hence, biodynamics is regarded as a promising road to tomorrow's integrated and sustainable agriculture.

Keywords Biodynamic farming · Principles of biodynamics · Farm management · Soil quality · Sustainable agriculture

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Introduction

Biodynamic agriculture is a type of alternative agriculture that is similar to organic farming but incorporates esoteric concepts based on Rudolf Steiner's beliefs (1861–1925). It was the first organic agriculture movement, having been formed in 1924 [18, 44, 55],Vogt & others, 2007). Biodynamics and other organic techniques have a lot in common. It encourages the usage of manures and composts while prohibiting the application of artificial chemicals to soil and plants. It emphasizes spiritual and metaphysical ideas while treating soil fertility, plant growth, and cattle care as environmentally interrelated responsibilities [6, 56, 82].

Biodynamic agriculture (BDA) was the first systematic method of organic farming as an alternative to the rise of high-input industrial agriculture in early twentieth-century Europe [21]. Concerns about food security and safety, environmental problems, and resource limitations have altered agriculture's possibilities. As a result, biodynamic farming has become a scientific focus in the last 20 years as an alternate way for achieving long-term sustainability. In the context of anthroposophy, the notion of biodynamic farming was established [12, 64].

Currently, biodynamic farming is the concern and practice of more than 5500 farmers globally, and the farming method has a very good preference among consumers of organic products [33]. Furthermore, research attempts to develop and approve biodynamic methods have always been an important concern of the community [21].

The main principles of biodynamic agriculture as stated by Rathod et al. [68] are as follows: restore the soil through the incorporation of organic matter,treat soil as a living system; create a system that brings all factors that maintain life into balance; encourage the use and significance of green manure, crop rotation, and cover crops; treat manure and compost in a biodynamic way; and have insights about the use of enzymes and hormones [2, 3, 41].

The objective of this paper is to review and give brief highlights about the concepts, principles, and applications of biodynamic farming. To review about biodynamic farming, different literatures, research works, and practical works have been reviewed. Different search engines were used in search of documents using keywords like biodynamic agriculture, organic farming, sustainable development, ecology, soil quality, and health. As much as possible, recent references were used to review.

The Myth of Biodynamic Farming

Biological dynamic agriculture is a system of agricultural management based on Rudolf Steiner's 1924 lecture series. He became worried about the degradation of food produced by farming practices that progressively relied on the addition of inorganic fertilizers and pesticides during the course of his life [10]. Biodynamics, widely regarded as the first alternative approach to agriculture, has grown over the previous century to encompass numerous organic farming practices with proven effects on land usage and crop output [9]. In fact, in both scientific and popular literature, biodynamic is frequently used interchangeably with organic farming. Biodynamic agriculture is more well-known in Europe, but its supporters in North America are growing [95].

Biodynamics, despite being veiled in overly romanticized metaphysical and spiritual conceptions, provides nothing in the way of actual, verifiable benefits. Its roots can be found in anthroposophy, and it is described as progressive, tolerant, enlightened, and environmentally conscious. Biodynamics is the most widely used kind of practical anthroposophy, second only to Waldorf institutions [35],Tyson, 2019).

Anthroposophy, a philosophy popularized by Rudolf Steiner in 1912, is openly racist, with roots in nationalism, right-wing populism, and esoteric spiritualism. Biodynamics had a strong influence on the "green wing" of German fascism in the 1930s, having identified philosophical parallels with National Socialism. Steiner's racial and environmental concerns, which centered on re-energizing the mystical connection between land and man, were likely a result of his concern for the welfare and eventual purity of what he regarded to be the superior race (Hansson, n.d.; [48]. These worries, combined with his mystical interpretation of soil and land, echoed the Third Reich's infamous "Blood and Soil" motto. In the face of rising political polarization, a resurgence of extreme right-wing populism in Europe, and a greater need to address climate change, the wine industry should recognize the dangers of pseudoscience and consider the political vulnerabilities of romanticized esoteric environmentalism and reactionary ecology [50, 84].

Modern Biodynamic Agriculture

The first contemporary organic agriculture was biodynamics. In 60 nations throughout the world, over 5000 farms covering over 400,000 acres have been certified. A Goethean observation of nature and its application to a farming system is a cornerstone of the biodynamic way of farming [12, 78]. This promotes an understanding of nature as a whole, a totality, and an organism with archetypal rhythm. Biodynamic farming is more than just a set of techniques,it is also a conceptual philosophy that applies to the farm's general structure. The foundation of biodynamics is the construction of a farm that functions holistically as an unbroken organism, with soil, animals, humans, and plants operating as "organs of a living organism" [19, 79].

The farm organism's health is dependent on each organ working in unison with the others, as well as with its surroundings. Human, animal, plant, mineral, and cosmic energies must all flow together. Following these objectives results in agriculture that is self-sustaining to the greatest extent possible. Biodynamic farms strive to create a nearly closed system, with as many of their inputs (such as fertilizers) originating from within the farm as possible [58, 87]. For example, most fertilizer needs are met by compost and legumes, while weed and pest control is typically achieved with mechanical or physical controls, homeopathy, rotations, and other non-commercial methods [60]. Crop growth and development is reliant on organic soil fertility, which is again reliant on well-managed livestock. Farms that are Demeter-certified must have livestock or a close association with a nearby livestock farm [7, 57].

Biodynamic is a trademark owned by the Demeter organization of biodynamic farmers and used to maintain production standards in both farming and food processing. Both consumers and producers of biodynamic produce are protected by the trademark. Demeter Worldwide is a non-profit organization made up of member countries; each country has its own Demeter organization that must adhere to international production standards (but can also exceed them) [24, 25, 61, 62].

Biodynamic farming is the management of a farm based on living organism principles. A wilderness forest is a good example of a living organism ideal. There is a great degree of self-sufficiency in all aspects of biological survival in such a system. Fertility and feed are produced as a result of the system's recycling of organic waste. Pest species are avoided because of their biological vigor and inherent biological and genetic variety. The system efficiently circulates water [26].

The farmer's understanding can reflect these ancient ideals of sustainability when agriculture brings nature one step closer to wilderness. The farm organism's vision extends beyond the fence line to incorporate both tangible and intangible factors at action. The climate, the earth's natural wildlife (above and below the ground), the sun's light and warmth, and more distant celestial effects are all examples. Biodynamic farming aims to bring all of these elements together in a holistic, living farm system. The resulting cuisine is incredibly clean and faithful to its essence, and it provides profoundly penetrating nutrients, which is critical for an increasingly ill human [34, 83, 90].

The goal in day-to-day practice is to establish a farm system that is less reliant on imported materials and instead meets its needs through the farm's living dynamics (*Biodynamic Farming Is on the Rise – but How Effective Is This Alternative Agricultural Practice? | Guardian Sustainable Business | The Guardian*, n.d.). The farm's biodiversity, which is designed so that waste from one section of the farm generates energy for another, increases the farm's potential for self-renewal and, as a result, makes it sustainable [38, 92].

This necessitates that a farm be regenerative rather than degenerative to the greatest extent possible. Consider the resources that are brought onto today's organic farm with caution. They are frequently linked to a natural resource offered by the earth. Petroleum for moving commodities, old mineral reserves, by-products of unsustainable agriculture-related industry, and the life of seas and waterways are only a few examples(*What Is Biodynamic Farming?—SunHawk Farms*, n.d.). Biodynamic farming has a significant social value in that it does not rely on mining the earth's natural resource base but rather on contributing to it (*Biodynamic Principles and Practices—Demeter USA*, n.d.; [75]

Trends in Biodynamic Agriculture

Biodynamic farming is regarded as "above and beyond organic" [12]. The fundamental distinctions between the two systems are due to the biodynamic agriculture's specific preparation [1]. Biodynamic farming is gaining popularity around the world [95]. The development of biodynamic farming is illustrated in Table 1.

Over the last 18 years, the number of farms has expanded by more than 47 percent, according to the data. Between 2004 and 2007, there were some changes, with the number of farms increasing dramatically. The expansion is linked to the establishment of the International Biodynamic Association and Council, as well as growing concerns about sustainability and biodiversity. The number of countries with Demeter-International certified biodynamic activity increased from 42 to 55. Germany had the largest (1552) biodynamic farms. Biodynamic farming, which is a method of preserving biodiversity and soil health, is gaining popularity among customers [12].

Table 1 Certified Demeter operations (2019, number)

Countries	Hectares	Farms	Processors	Distributors
Austria	5.720	186	35	10
Brazil	1.004	27	25	6
Denmark	2.384	33	9	8
Egypt	2.839	60	8	6
Finland	404	17	5	4
France	13.665	511	108	42
Germany	85.395	1552	403	124
Great Britain	3.734	100	43	13
India	5.417	403	5	1
Italy	9.640	286	51	43
Luxembourg	530	13	3	2
Netherlands	6.337	136	42	26
New Zealand	336	21	3	1
Norway	685	23	9	3
Slovenia	216	33	3	1
Spain	6.243	133	27	12
Sweden	859	16	6	8
Switzerland	5.556	255	63	54
USA	9.001	118	88	36
Argentina	1.164	36	6	1
Bulgaria	0	0	0	1
Chile	1.379	22	0	3
Czech Republic	3.541	5	0	1
Hungary	6.319	26	1	2
Lithuania	1.389	11	0	1
Poland	3.520	13	0	0
Turkey	1.102	153	1	2

Source: Beluhova-Uzunova and Atanasov [12]

Biodynamic Farming and Sustainability

Effect of BD on Soil Quality

Soil quality is the capacity of a soil to function for specific land uses or within ecosystem boundaries. Soil quality directly affects plant growth, crop production, and quality. Studies have shown that the biodynamic farming systems generally have better soil quality, lower crop yields, and equal or higher net returns per hectare than their conventional counterparts [23, 70, 71].

After 2 years of farming in CISH, Lucknow, researchers looked at various chemical and biological aspects of soil under biodynamic farming. They discovered that after 2 years of farming, there is a significant rise in accessible phosphorus, potassium, and organic carbon content, as well as a high microbial colony of yeast, mold, and bacteria (R. A. [67].

The importance of biodynamic farming in soil carbon sequestration is also investigated. Researchers compared two long-term experiments that are 33 years of "K-trial" of Sweden and 28 years of "DOK trial" of Switzerland under organic and biodynamic farming in

different depth of soil. They discovered that biodynamic farming sequesters a greater quantity of carbon. Carbon sequestration (or increasing the amount of carbon stored in vegetation and soil) is a preventative technique for reducing the build-up of carbon dioxide (CO2) in the atmosphere. At the DOK trial and K trial, soil organic carbon was maintained at the same level, with a modest gain in the BD system, whereas soil organic carbon was lost in the organic farming systems (Raupp et al., 2006). Likewise, another group of researchers studied the chemical properties of soil after two crop rotations under control, biodynamic, organic, conventional, and mineral system in New Zealand. They revealed that all of the soil microbial features, such as microbial biomass, microbial respiration, and soil enzyme activity, are higher in biodynamic farming than in other agricultural systems. The microbial population in BD preparations was found to be significant, particularly that of 502 and 506. A number of bacterial and fungal strains were shown to have the ability to inhibit fungal plant diseases. This could also explain why there was a considerable and unambiguous difference in dehydrogenase, protease, and phosphatase activity between agricultural methods, with the biodynamic system having the highest levels [30].

BDA as a Circular Economy and Its Effect on Productivity

A circular economy is a production and consumption model that incorporates allocation, leasing, reusing, repairing, refurbishing, and recycling existing materials and products for as long as possible. BDA is a production and consumption strategy that entails the recycling of wastes and by-products in order to regenerate farm products. As a result, BDA as a circular economy decreases material use, redesigns things to be less resource intensive, and recycles "waste" to create new materials and products. One of the goals of the circular economy is to have a positive impact on ecosystems and to combat natural resource exploitation. As a result, BDA as a circular economy has the potential to reduce greenhouse gas emissions and raw material consumption, improve agricultural production, and eliminate negative externalities caused by the linear model.

In order to assess the effect of BDA on productivity, some research activities were carried out. For example, the yield of various fruits and vegetables under conventional and biodynamic methods in CISH, Lucknow, was examined by investigators. They found a markedly higher yield in case of cauliflower, cabbage, gooseberry, and mango under biodynamic system than that of conventional system (R. A. [67]. Similarly, investigators studied the effect of biodynamic manure (BD 500 and BD 501) in combination with vermicompost and farm yard manure on growth and yield of cumin (*Cuminum cyminum* L.) [80]. They found that using BD 500 and BD 501 in combination with either FYM at 6t/ha or vermicompost at 2t/ha increased cumin seed yield by 20.56 percent and 12.85 percent, respectively, as compared to using FYM at 6t/ha and vermicompost at 2t/ha alone.

Biodynamic agriculture has the potential to improve livelihoods, income, and societal benefits. Biodynamic (organic) farming is more profitable than conventional farming, according to a meta-analysis of studies from different nations [31]. A statement supporting this was reported from study about the "Economic and Social Sustainability through Organic Agriculture: Study of the Restructuring of the Citrus Sector in Spain" [86]. As a result of the lower labor input and increased market appreciation, organic farming has been proved to produce better economic and financial results.

In another study, the gross revenues of biodynamic and conventional farms were identical. Biodynamic farmers, on the other hand, made more money because their costs

were lower than conventional farmers [12]. A study in Germany found that biodynamic gardens yielded lower yields of all vegetable crops over a 6-year period than conventional ones. However, biodynamic products had higher prices, which meant that most biodynamic vegetables had resulted in greater economic returns [74]. Earlier studies also reported that majority of biodynamic products were offered as certified organic or biodynamic at premium prices of up to 25% more than conventional products. Most biodynamic farms showed lower year-to-year and unpredictable gross revenue than conventional farms, which is significant for economic sustainability [72].

In another independent investigation, biodynamic yields were 3.6%t lower than conventional yields. According to financial indications, prices in biodynamic farming were 57% higher than in conventional farming, making biodynamic farming more profitable than conventional farming (gross revenue, gross margin, net margin, net income, and capital income were 50.7, 99.9, 122.9, 150.4, and 166.9%, respectively, higher in biodynamic than in conventional). The price equilibrium point (PEP) for biodynamic farming was 3.4% higher, whereas the leveling point for conventional farming was 36.9% higher. The greater biodynamic trade prices than conventional trading prices caused a PEP that can cover higher costs and improve profitability [76].

Effect of BD on Nutritional Quality of Produce

Biodynamic agriculture restores the normal antioxidant production of plants, increasing the nutritional value of biodynamic fruits and vegetables at the same time [36, 59] According to research findings, two antioxidants, beta-carotene and vitamin C, are 14 and 48 percent higher, respectively, in foods produced through biodynamic agriculture. Hundreds of different antioxidants have yet to be tested, but their concentrations are expected to be higher as well (*Biodynamic Food Nutrition*, n.d.).

Heimler et al. [43] evaluated different production systems (conventional, organic, and biodynamic) and discovered that Batavia lettuce (*Lactuca sativa* var. capitata) grown under biodynamic conditions had the highest polyphenol concentration. Polyphenols are desirable secondary chemicals in food that boost nutritional value [47]. The highest total phenolic content was observed in biodynamic red beets (*Beta vulgaris*), followed by organic red beets, while the lowest amount was reported in conventional red beets [11]. Organic mangoes (*Mangifera indica*) had the highest total phenolic content, whereas biodynamic and conventional mangoes had the lowest [49].

Biodynamic chicory (*Cichorium intybus*) and Batavia lettuce (*Lactuca sativa* var. capitata) exhibit more antioxidant activity than conventional and organic produces [42, 43]. It was also found that biodynamic red beet (*Beta vulgaris*), biodynamic strawberries, and biodynamic mature green and ripe mangoes (*Mangifera indica*) all showed significantly higher antioxidant activity than conventional and organically grown items [11].

Effect of BD on Pest Management

Biodynamic pest management relies on having high biodiversity—a wide variety of plants, insects, and animals in the ecosystem. Biodynamic has its own principles and mechanisms to manage disease and pests [45, 51]. Some of the pest management methods include the use of cow horn silica to control fungal attack and biodynamic neem-based liquid pesticides for the control of soft pests (aphids, jassids, flies etc.). The use of nettle spray

for the management of hard insects can also be mentioned. Spray of biodynamic pesticides prepared from cow urine, neem, castor, and Vitex spp. leaves extract are good for the management of hard pests (R. A. [66]. Disease management using biodynamic principles also include the use of two sprays of Cow Horn silica (BD-501) at flowering and fruit development stage, biodynamic tree paste/cowdung paste for the control of gummosis and dieback, spraying of horsetail (*Equisetum arvensis*)/casuarina leaves extract for the control of fungal diseases [96].

In BD system, bio-pesticides can be categorized into different groups. Bio-pesticides are naturally occurring substances that control pests by non-toxic mechanisms. Conventional pesticides, by contrast, are generally synthetic materials that directly kill or inactivate the pest [27], whereas microbial pesticides consist of a microorganism (e.g., a bacterium, fungus, virus, or protozoan) as the active ingredient. Although each active ingredient is somewhat specialized for its target pest, microbial pesticides can control a wide range of pests [89]. The other groups called Plant-Incorporated-Protestants (PIPs) are pesticidal compounds produced by plants as a result of genetic material introduced into the plant. Scientists can, for example, take the gene for *Bacillus thuringiensis'* pesticidal protein and insert it into the plant's genetic code. The plant then produces the chemical that kills the bug instead of the *Bacillus thuringiensis* bacteria [28, 29]. Another category is that of bio-insecticides, which are organic formulations that are advised for controlling insects that feed on crops. In various aspects, they differ from chemical pesticides. They contain living bacteria that create poisons that kill insects by poisoning their stomachs [4, 81].

The Scientific Bases of Biodynamic Farming

Biodynamics (BD), as well as related organic and sustainable farming approaches, are gaining popularity. However, there are other areas of BD that are little understood as a science and are shrouded in legend [25]. Although some practitioners claim that biodynamics is a cure-all, it obviously has the potential to improve agricultural and horticultural production while also teaching us about helpful microbes (*The Science Behind Biodynamics | EOrganic*, n.d.).

Biodynamic agriculture differs from organic agriculture in that it employs specialized strategies intended at enhancing plant life by bolstering plant, ground, and environmental interactions (*Biodynamic Agriculture – Dictionary of Agroecology*, n.d.). The concept of the farm as an autonomous and living organism and structure underpins biodynamic agriculture. It is often seen as a search for a balance between the industrial system and its surroundings. Multiannual crop rotations, the use of mixed species with mutual benefits, and the use of compost derived from animal droppings are all shared by biodynamic and organic agriculture [40, 57].

Nutrient addition (mainly micronutrient), microbial inoculation, plant immunity activation, plant hormones, and microbial signaling are the scientific foundations of BD preparations. Some nutrients are present in BD preparations, albeit only in trace amounts. The modest amount of preparation material utilized has no discernible influence on the macro- and micronutrient content of the soil. It is virtually hard for preparations to have any detectable effect on macronutrient or even micronutrient content when applied to soil [52],L. C. [65]. Small amounts of nutrients can be directly delivered to and taken up by plants using foliar application. Sometimes, it can also be effective treatment for

aged seeds (MUH\.IE et al., 2021,[54]. Micronutrients can benefit plants even at very low concentrations if the nutrient is insufficient for the plant's growth stage [8, 22, 46].

Microbial signaling can impact the make-up and/or activities of microbial communities, despite the difficulty of changing them directly. Microorganisms communicate with one another in a variety of ways, including through exchanging volatile or diffusible chemicals [17, 93]. Individual bacteria can release trace amounts of hormones, signals, and other substances, which can cause changes in neighboring organisms' activities. Antibiotics are a well-known example, and many soil and compost microorganisms create them to inhibit the growth of other populations. The chemistry and complexity of microbial signaling is a new frontier in microbiology and biodynamic agriculture [63],R. A. [66].

For disease inhibition, biodynamics is increasing popularity and interest. Plant pathogenic organisms may be suppressed by preparations due to competition, predation, antagonism between bacteria in the preparations, or inhibitory chemicals produced by the microorganisms [77]. Some compounds can potentially cause plants to develop "systemic resistance." This is comparable to a plant vaccination or immune system stimulation in general [73]. Plant defense responses like the synthesis of chitinase (an enzyme that breaks down fungal cell walls) and thickening of plant protective cell walls can be boosted before a pathogen attacks [32].

When a pathogen attacks, the plant is ready for defense and stands a much greater chance of survival. Many materials, including soluble silica solutions, have been reported to cause systemic resistance. The biodynamic preparation 501 is created by finely grinding and fermenting quartz or feldspar, and it may be a classic way of establishing plant systemic resistance (Fig. 1). Horticultural industry uses plant hormones on a regular basis. They are used to stimulate budding, roots, and other physiologic changes in plants. Several investigations have found plant hormones in BD preparations, such as auxins and cytokinins, or confirmed hormone-like effects on plant growth [5,

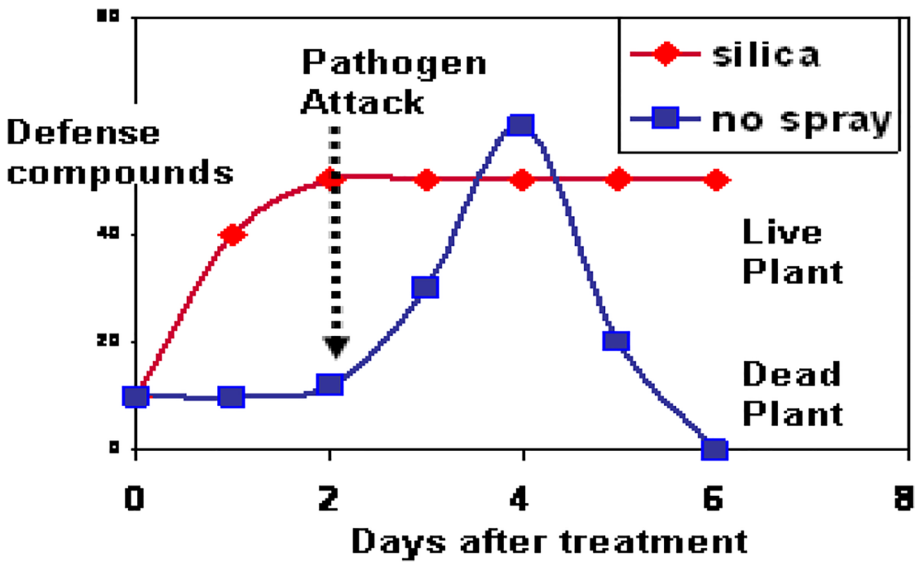

Fig. 1 Plant immunity stimulation after treatment with silica spray [25]

37]. A study provided a strong indication of a stimulation of natural defense compounds in grapes grown under biodynamic cultivation [20].

Conclusion

Biodynamic agriculture is an old but new alternative agriculture for long-term sustainability. However, it is poorly understood and implemented. In the last 20 years, biodynamic farming has become a scientific focus as a means of ensuring circular economy and long-term sustainability. The concept of biodynamic farming was developed in the context of anthroposophy.

Biodynamic farming is important to achieve sustainability in a number of ways such as improvement in soil carbon sequestration and enhance productivity or yielding potential and nutritional quality of produce. Biodynamics is also gaining popularity and interest for insect pest and disease prevention. Plant pathogenic organisms may be inhibited by preparations as a result of competition, predation, antagonism between bacteria in the preparations, or inhibitory compounds produced by the microorganisms.

In my opinion, the efficiency and productivity of biodynamic farming has the potential to make very important contributions for better policy decisions and to a better understanding of biodynamic farming in general as a system with agronomic, economic, and environmental dimensions. However, most analyses of agricultural productivity concentrate on production efficiency. However, production resilience is ignored in a changing climate.

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Declarations

Ethics Approval and Consent to Participate Not applicable.

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