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VII. SUMMARY

The main objectives of this study were to: 1- Assess the effect of applying the biodynamically farming practices to newly reclaimed soils for 20, 10, and 5 years on the integrated soil quality and sustainability at the farm level. 2- Understand the mechanisms and processes of soil degradation or aggradations that drive soil change to help developing sustainable farm practices that are necessary for soil environmental health and agriculture sustainability. 3- Investigate the relevance of beneficial free living nematodes as faunal soil quality indicator.

Sekem farm was selected as a study site. It is established over an area of 55 ha (105 feddan) of desert land in El-Sharkia Governorate near by Belbase city, north east of Cairo. It is a certified biodynamic farm by a Center of Organic Agriculture in Egypt (COAE) and Demeter standards for biodynamic farming system in Germany. Composite surface soil samples (0.0-0.15m) were collected from three soil plots biodynamic cultivated for 5, 10, and 20 years, the three soil samples were given the symbols of S5,S10, and S20, respectively. Irrigation water and farm compost samples were collected.

Farm compost properties such as dry matter, organic carbon and nitrogen, plant nutrients, pH and EC were determined. Main chemical characteristics of underground well water were determined.

The main soil physical indicators such as soil texture, soil Bulk density, and water holding capacity were determined. Main soil chemical indicators such as electrical conductivity, available phosphorous and potassium, total organic carbon (TOC), total nitrogen (TN), soil labile carbon (LC), soil labile nitrogen (LN), total soluble nitrogen (TSN), hot potassium chloride extractable nitrogen (Hot-KCl-N), and phosphate-borate buffer extractable nitrogen (p-Borate- N) were determined. Also, main soil biological indicators such as microbial biomass carbon (MBC), microbial biomass nitrogen (MBN), microbial respiration (CO_2-C), and soil mineral nitrogen (NH_4) were determined. On the other hand, free living nematodes (FLN) and plant parasitic nematode (PPN) were determined as faunal indicators. five ecological indices were computed for describing nematode communities in each soil sample, used as indicators of soil ecosystem quality: Maturity index MI for all free living nematodes, MI index for free living nematodes excluding opportunistic colonizers (C-p=1) MI_{2-5}, Enrichment index EI, Channel index CI, and Biodiversity of trophic groups (Shannon-Weaver diversity index (H') or Hill's NI).

Completely randomized statistical design (CRD) was applied to each of the three soil types that received compost with five rates and replicated three times. Analysis of variance (ANOVA) was carried out to determine the effect of the application rates of either farm or modified compost on selected parameters for each soil. Least significant difference values (LSD) at ($P<0.05$) were calculated when the treatment effects were significant.

To assess the effect of applying the biodynamically farming practices to newly reclaimed soils for 20, 10, and 5 years on the integrated soil quality and sustainability, changes in soil attributes in relation to soil functions that promote plant growth and relate to soil environmental health were monitored. It is impossible to monitor changes in the absolute values of the soil attributes that relate to these soil functions. Monitoring of the selected soil criteria with universal threshold values that can serve as indicators of change in soil quality with the time of cultivation is possible and can yield useful information in trends of soil quality and serve as indicators of soil sustainability.

Six soil indicators were selected to represent two soil functions for plant productivity and environmental soil health; soil bulk density (BD) in relation to soil texture, total organic carbon (TOC), soil salinity (EC) which are the three indicators directly related to soil productivity, whereas microbial biomass carbon (MBC), microbial quotient (MBC/TOC, MBCQ), and specific microbial respiration quotient (qCO_2) which are the three indicators directly related to soil health.

Obtained soil texture of S10 was sandy clay loam while the other two soils had sandy loam texture. Soil bulk densities of the three soils were 1.21, 1.25, and 1.26 Mgm^{-3} of S5, S10, and S20, respectively. The value of the soil pH was 8.1 in the three soils. EC values were 7.27, 5.34, and 3.37 dS/m for S5, S10, and S20, respectively. Soil organic matter content in S5 and S20 accounted to 1.75 and 1.91 kg C m^{-2}, respectively. Microbial biomass carbon (MBC) was estimated to be 21.77, 48.97, and 77.04 g C/m^2 soil of S5, S10, and S20, respectively, Carbon microbial quotient was estimated to be 1.24, 2.29, and 4.04 % in S5, S10 and S20, respectively. The obtained results of carbon mineralization rate in S5, S10, and S20 using cumulative CO_2 during 28 days incubation were 7.5, 9.85, and 7.13 g CO_2-Cm^{-2} soil d^{-1}, respectively. The calculated qCO_2 for S5, S10, and S20 was estimated by 14.35, 8.38, and 3.86μg CO_2–C h^{-1} mg^{-1} MBC. The average of the respective indicators to soil environmental health was computed for sustainable index of the soil environmental health which was equal to 0.6, 1.22, and 2.02 for S5, S10, and S20, respectively. Also, the averages of soil productivity indicators were equal to 1.22, 1.36, and 1.44 for S5, S10, and S20, respectively. The sustainability index of soil degradation or sustainability was equal to 0.91, 1.29, and 1.73 for S5, S10, and S20, respectively.

The results of sustainability calculation showed that the least developed soil (5) did not reach the threshold level of sustainability index whereas the other two soils were judged to the sustainable. The sustainability index was increased with increasing the soil development under the biodynamic farming practices which used in the certified Sekem farm. The six indicator's value of S10 and S20 were plotted on a radar graph with a threshold cobweb bounded area. The graph is a simple and good tool to immediately visualize and identify the specific indicators that contribute to reduce sustainability. A nonsustainable situation was found in S5 with three of six indicators below threshold bounders. The three defected indicators in S5 were MBCQ, qCO2, and EC. Although S10 and S20 were judged sustainability; two defected indicators were identified in S10 (EC and qCO_2) and qCO_2 was the only defected indicator in S20. The microbial respiration quotient was the most responsible indicator that retarded soil sustainability.

Understand the mechanisms and processes of soil degradation or aggradations that drive soil change to help developing sustainable farm practices that are necessary for soil environmental health and agriculture sustainability. Results of obtained microbial biomass carbon (MBC) by reacting four rates of farm and modified composts with S5, S10, and S20 for 14 and 70 days were fluctuated through out the 70 day incubation and ended with low MBC than their initial values of 49.0 and 77.0 g C m-2 soil to be 29.3 and 64.9 g C m^{-2} soil for S10 and S20, respectively. Results of the obtained MBC by reacting four rates of the modified compost with soil samples, collected from the soil plots of S5, MBC increased after receiving different compost rates but to a lower extent than those of the farm compost treatments after 14 days incubation. As the incubation continued to 70 days, the applied compost rates at 40 and $80m^3fed^{-1}$ were less efficient in increasing the MBC as compared to the farm compost efficiency. Considering the biodynamically cultivated for soil 10 years (S10), MBC was drastically decreased after receiving the different rates of the modified compost after 14 days incubation except for the highest compost rate treatment compared with the untreated soil. As the incubation continued to 70 days, added modified compost to S10 at the different rates was more efficient on increasing MBC than the farm compost. The percentages of MBC increasing were 43.6%, 14.4%, 44.7%, and 11.6% for S10 treated with 20, 40, 80, and 120 m^3 fed^{-1} modified compost, respectively. Modified compost added to S10 at the rates of 20 and 80 m^3 fed^{-1} significantly increased the MBC values to 97.8 and 137.6 g C m^{-2} soil, respectively. Considering the biodynamically cultivated soil for 20 years (S20) modified compost added at the three higher rates significantly increased the MBC at the same probability level of 0.05 compared to the untreated soil after 14 day incubation. As the incubation continued to 70 days, MB growth suffered drastic reduction in all compost treatment except for the rate of 40 m^3 modified compost fed^{-1} in comparison to untreated soil. The effect of farm compost applications at four rates to S5, S10, and S20 on the changes of microbial quotient during 70 day incubation showed higher microbial quotient than in the case of unamended soil treatments. Different increases in the microbial quotient were obtained in all amended soil treatments except for the treatments of highest rate application of the farm compost (120$m^3 fed^{-1}$) to S5, S10 and S20.

After 70 day incubation, the highest microbial quotients were assigned to the application of 40 and 80 $m^3 fed^{-1}$ in the three soils. The microbial quotients of S5, S10, and S20 that was treated with 40 $m^3 fed^{-1}$of farm compost were 5.67, 2.81, and 6.05, respectively. Amending the soils with 40$m^3 fed^{-1}$of farm compost increased the microbial quotient over the control by 153%, 123%, and 150%, respectively. Generally, the farm compost treatments showed a preferential effect on MBCQ in the three soils compared to the effect of the modified compost. Considering the soil cultivated for 5 years, microbial respiration, in terms of g CO_2-C m^{-2} soil, for amendment treatments was highest in soil received 20 and 80 m^3 compost per feddan and was lowest in soil received 120m^3compost per feddan after 7 days of incubation. Percentage of carbon losses relative to carbon inputs were 54.57% and 13.62% from soils received 20 and 80 m^3 compost per feddan, respectively, after 7 days incubation. Also, percentage of the accumulated C losses from soils received 40 and 120 m^3 compost rates per feddan were estimated to be 35% and 8.73%, respectively, after 7 days incubation. Considering the soil cultivated for 10 years, the different treatments showed the same trend as of S5, with relatively higher quantities of carbon loss from all treatments. Microbial respiration for amended treatments, in terms of g CO_2-C m^{-2}, soil was the highest in soil received compost rate of 120 m^3 fed^{-1} throughout the 49 days of incubation. Considering the soil cultivated for 20 years, As the incubation continued to 49 days, the total losses of the carbon storage expressed as percentage of the carbon inputs of 20 40, 80, and 120 $m^3 fed^{-1}$ was estimated to be 90.0%, 48.64%, 24.72%, and 16.65%, respectively. Results of effect of the farm compost on the decay of total OM storage indicated that the pattern of organic matter decomposition was similar in the three soils. Changes in MBC and qCO_2 values showed a variable trend between the unamended S5, S10, and S20 at the end of the incubation. The MBC in S5 was significantly increased from the initial 21.77g C m^{-2} soil to 34.3g C m^{-2} soil and the qCO_2 decreased from 14.35 to 6.24 mg CO_2-C g^{-1} MBC h^{-1}. This may be translated into a higher microbial biomass growth and lower specific respiration rate which reflects the presence of optimum conditions for biomass growth and activity. With the unamended treatments of S10, and S20, the MBC decreased from the initial values of 48.97 and 77.04, respectively down to 29.3 and 64.9 g C m^{-2} soil, respectively after 70 day incubation. Addition of the different rates of the farm compost induced a reduction in the respiratory quotients for S5, S10, and S20 than in the unamended soils except for the highest rate of applying compost to S5.

Total nematode numbers were estimated to be 181X10^3, 188X 10^3, and 359 X 10^3 of FLN per square meter in the surface layer of S5, S10, and S20 respectively. The identified genera in Sekem soil were *Alaimus*, *Aphelenchus*, *Aphelenchoides*, *Cephalobus*, *Panagrolaimus*, *Plectus*, and *Rhabditis*. Diversity index (H') failed to differentiate between the effects of different biodynamic cultivation periods on the soil quality. Channel index (CI) failed to be a soil quality indicator. The calculated EI for S5, S10, and S20 were 56%, 72%, and 93%. The recorded values of MI for S5, S10, and S20 were 1.61, 1.76, and 1.22.

Numbers of FLN in Sekem farm compost treatment were decreased with biodynamic management periods increased. The highest NFLN 356X10^3 nematode m^{-2} soil was recorded in 5 years (S5) followed by 20 years (S20) with 277X10^3 nematode m^{-2} soil and 10 years (S10) with 216X10^3 nematode m^{-2} soil. On the other hand, NFLN in modified compost application were increased to the highest number of 777X10^3 nematode m^{-2} soil at S10 then decreased again to be 344X10^3 nematode m^{-2} soil, which nearly equal numbers of S5 (437X10^3 nematode m^{-2} soil). Data of compost application rates indicated that NFLN were increased as a result of compost application. The highest NFLN of farm compost was recorded in S5 (149%) followed by S10 (136%) and S20 (50%). The same trend was recorded in modified compost application but the highest number was recorded at S10 with 749% increase followed by S5 (205%) and S20 (86%). The genera presented at S5 were *Alaimus* (Ba_4), *Aphelenchus* (Fu_2), *Aphelenchoides* (Fu_2), *Cephalobus* (Ba_2), *Panagrolaimus* (Ba_1), and *Plectus* (Ba_2). *Aphelenchus* (Fu_2), *Aphelenchoides* (Fu_2), *Cephalobus* (Ba_2), *Panagrolaimus* (Ba_1), *Plectus* (Ba_2), and *Rhabditis* (Ba_1) were presented in S10. However, the genera *Alaimus* (Ba_4), *Aphelenchus* (Fu_2), *Aphelenchoides* (Fu_2), *Cephalobus* (Ba_2), *Panagrolaimus* (Ba_1), *Plectus* (Ba_2), and Rhabditis (Ba_1) were found in S20. The most prevalent genera in S5 were *Cephalobus* (Ba_2) 32.6% frequency of occurrence, *Panagrolaimus* (Ba_1) 47.1%, and *Aphelenchus* (Fu_2) 7.8% with average numbers of 106X10^3, 1237 X10^3, and 321 X10^3nematode m^{-2} soil, respectively. However, the genera *Alaimus* (Ba_4) 4%, *Aphelenchoides* (Fu_2) 3.1%, and *Plectus* (Ba_2) 5.5% were less common and the average numbers of these genera were 43X10^3, 197 X10^3, and 273 X10^3nematode m^{-2} soil, respectively. The genera, *Panagrolaimus* (Ba_1), *Plectus* (Ba_2), and *Cephalobus* (Ba_2) were most prevalent in S10 with 43, 27.6, and 22% of occurrence and average number of genera was 837X10^3, 633 X10^3, and 557 X10^3nematode m^{-2} soil, respectively. While, *Aphelenchus* (Fu_2), *Rhabditis* (Ba_1), and *Aphelenchoides* (Fu_2) were less common with 1.1-4.8% of occurrence and average number of genera was 117X10^3, 30 X10^3, and 21 X10^3nematode m^{-2} soil, respectively. In S20, the genera *Panagrolaimus* (Ba_1), *Cephalobus* (Ba_2), *Plectus* (Ba_2), and *Aphelenchoides* (Fu_2) were most prevalent with 38.2, 19.7%, and 11.6% of occurrence and average number of genera was 1184X10^3, 715 X10^3, 571 X10^3,and 397 X10^3nematode m^{-2} soil, respectively. While *Alaimus* (Ba_4), *Aphelenchus* (Fu_2), and *Rhabditis* (Ba_1) were less common with 0.7-2.5% of occurrence and average number of genera was 130X10^3, 21 X10^3, and 88 X10^3nematode m^{-2} soil, respectively.