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Population Dynamics Of Earthworms In Cauvery Delta Areas In Relation To Soil Properties

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Abstract:Population dynamics of earthworms in the two different cultivable land areas – wet land cultivable areas (WLCA) (including paddy, banana and sugarcane fields) and dry land cultivable areas (DLCA) (including coconut and groundnut fields) of five different pedoecosystems in the Cauvery delta areas of Sirkazhi taluk, Nagapattinam district, Tamil Nadu state, India with reference to various soil ecological parameters have been studied, for the first time during the period from November 2011 to April 2012. The WLCA (paddy> sugarcane> banana fields) harbor maximum population dynamics of earthworms whereas low in DLCA (groundnut> coconut fields). This may be due to presence of more edaphic factors - OC, N and moisture. Along with these, microorganisms as protein and N rich food support for earthworm growth and reproduction. They are involved synergistically influence the density and biomass of earthworm at maximum. In the five different pedoecosystems of Cauvery delta areas, only two types of soil namely clayloam and sandyloam are found and this variations are due to the nature of earlier agricultural activity and the nature of soil texture. Population dynamics of earthworm in different pedoecosystem are found in soil having 17.6–23.8% range of moisture and among pedoecosystems, more moisture content and more earthworm population dynamics are found in paddy field, followed by sugarcane, banana, groundnut and coconut field. This is due to adequate and frequent irrigation, more water holding capacity, higher microbial activity, OC, N and other nutrient content of the soil.

In the five different pedoecosystems, are found in soil having 17.3 – 18.5C ranges of temperature. This indicates the ideal and optimal temperature for earthworm survival and reproduction in these areas. The population dynamics of earthworm are found within a narrow range of pH (6.7 – 7.3) and this variations of soil pH within these delta areas are due to the variation of salinity and acidity nature of the soil. The higher occurrence of maximum density and biomass of earthworms at WLCA as compared to DLCA is supported by higher OC (62-69%) of the soil of different pedoecosystems. The C:N ratio recorded in WLCA ranges from 2.09 to 2.21 and in DLCA ranges from 2.7 to 4.9. This indicate the adequate level of C and N in the soils of different cultivable land areas that support for the survival, distribution, abundance and density of earthworms. The WLCA are found to shows more N, P and K content than DLCA. This is due to the naturally available nutrient contents of soil/optimal moisture/soil input of organic materials during agricultural activity/enhanced nutrient mineralization by the earthworm – microbe symbiosis and enhanced microbial activity. Among the two different cultivable areas, more microbial activity are found in the WLCA than DLCA. This indicate the presence of optimal moisture, more OC, N and microbial population. Finally, it may be suggested that the synergistic effect of soil ecological parameters, even though both positively or negatively correlated with each others of different pedoecosystem of Cauvery delta areas had more influence on population dynamics of earthworms.

Keywords: Earthworms, Population dynamics, Cauvery delta areas, Pedoecosystems, Soil ecological parameters.

INTRODUCTION

The earthworm fauna of India is very rich and diverse. Reynolds (1994) reported world-wide occurrence of 3,627 terrestrial earthworm species, with an average annual addition of 68 species. In the Indian subcontinent (including Andaman and Nicobar islands) earthworms are represented by 509 species in 67 genera under 10 families indicating a high degree of diversity in this region compared to other areas (Julka, 1993). According to Julka (1993) majority of them are endemic and belong to 47 genera and the remaining 20 genera are peregrine, being passively introduced usually by man. Studies made on the distribution, diversity, abundance and biomass of earthworms of northeast India were mainly from Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram and Sikkim by Stephenson (1921), Gates (1972), Julka (1988), Lalthanzara et al., (2011); Tripura by Chaudhuri et al., (2008); Chaudhuri and Nath (2011); Orissa by Mishra and Dash (1984); Central Himalaya by Bhadauria et al., (2000, 2012) and South India particularly very little in Tamil Nadu by Ismail et al. (1990); Karmegam and Daniel (2000, 2001); Karnataka by Kale and Krishnamoorthy (1978) and Puducherry by Sathianarayanan and Khan (2006). But there is almost nothing to mention about the earthworm fauna of Tamil Nadu very particularly in the Cauvery delta areas. Also, the density and biomass of earthworms in different habitats under tropical/subtropical climatic conditions are given in the Table - 1.

India is an agrarian country. In Tamilnadu, the Cauvery delta districts (Thanjavur, Thiruvarur and Nagapattinam), covering 8.21 lakhs hectare area play a major role in various agricultural activities throughout year and about 40-45% of crop productivity is obtained from these areas. India though predominantly agrarian is currently facing severe perturbation of soil quality and health. To restore these, the practice of organic farming through vermicomposting and encouraging the activities of soil invertebrates particularly earthworms in agriculture are essential. India with rich variety of earthworms (509 species) has not exploited this potential. Therefore study is necessary on identifying indigenous composting earthworms in Cauvery delta district of Tamilnadu and their potential role in organic farming. Extensive exploration of indigenous earthworm species in these areas, particularly Sirkazhi taluk of Nagapattinam district with five different pedoecosystems is expected out of this work. For the study of community structure of indigenous earthworms in the Cauvery delta areas and their potential role in vermicomposting, the first step for the above is to study the population dynamics of earthworms. Hence the objective of the research work was programmed to study the population dynamics of earthworms (total density and biomass) in Cauvery delta areas, for the first time, particularly in Sirkazhi taluk of Nagapattinam District of Tamil Nadu state in relation to soil properties with five different pedoecosystems of two different cultivable land areas.

MATERIAL AND METHODS

Study areas and site selection for earthworm survey

An extensive population dynamics of earthworm survey was carried out during November 2011 to April 2012 in twelve different villages like Aarpakkam (S1), Kunnam (S2), Pazhaiyapalayam (S3), Sembadhaniruppu (S4), Manikiramam (S5), Aharaperunthottam (S6), Marudangudi (S7), Mudalaimedu (S8), Nangur (S9), Kadiramangalam (S10), Koothiyampettai (S11), and Natham (S12), of Sirkazhi taluk, Nagapattinam district, Tamilnadu state, India. This taluk is one of the dominant Cauvery delta taluk, one among the eight revenue taluk of Nagapattinam district, covering an area of 441.96sq/km, located between latitude 1114 N and longitude 7944 E/ and is almost encircled in the north side of Karaikal (union territory of Puducherry), south side of Tharangempadi taluk and west side of Mayiladuthurai taluk of Nagapattinam district and east side of Bay of Bengal. The collection and survey of earthworm sampling sites and soil analysis of different cultivate lands (S1 – S12) of Sirkazhi taluk of different habitats are depicted in Figure 1.

Earthworm sampling and population dynamics

Earthworms were collected from five random samples of 25 x 25 x 30 cm, atleast 5 m apart at a period of November 2011 to April 2012 with two different cultivate land areas like wet land cultivable area (WLCA) which includes paddy, banana and sugarcane field and dry land cultivable area (DLCA) which includes coconut and ground nut field. The collected earthworms (0-30 cm depth) were hand sorted on a plastic sheet and segregated into age – wise. In the present study, only clitellate earthworms were used for population dynamics of earthworms analysis. The density of earthworm was calculated as the number of individual present per metre square and biomass was determined as present weight (wet).

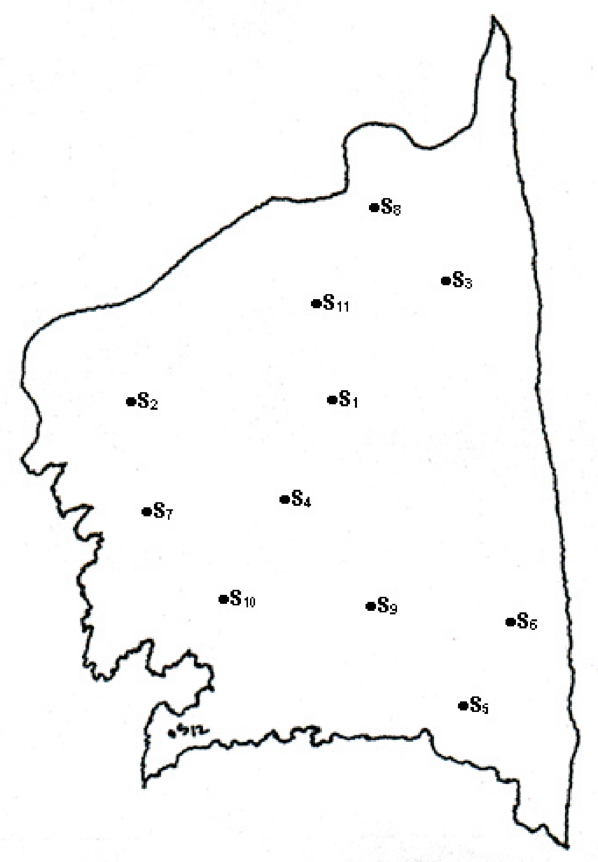

Figure 1. Map showing collection and survey sites of earthworm population in Cauvery delta area's, Sikazhi taluk, Nagapattinam district, Tamilnadu state, India

Soil Analysis

The soil samples were collected from three different strata (0 -10 cm, 10-20 cm and 20-30 cm depths) of different cultivable land areas by digging 30 cm depth at the time of earthworm sampling. The soils of different strata were thoroughly mixed, air-dried, ground and passed through sieves of fine mesh (0.2 mm size) and kept in plastic bag for chemical analysis by using standard methods. The soil types were identified with the help of Department of Earth Science, Annamalai University, Annamalainagar. Temperature (C) at 0-10 cm depth was measured by using a soil thermometer and soil moisture content (0-10 cm depth) was estimated gravimetrically on a wet weight basis by oven drying at 105C. Soil pH was measured by the method described by ISI Bulletin (1982). 5 gram of dry soil was taken in a 100 ml beaker and 50 ml of distilled water was added. The content was mixed well with using a glass rod. After 30 minutes, the pH was determined by using digital pH meter (Model-Global DPH 500). The soil sample of different pedoecosystems were analysed for organic carbon (Walkley and Black, 1934), total nitrogen (Jackson, 1962), available phosphorus (Olsen et al., 1954), available potassium (Stanford and English, 1949) and dehydrogenase activity (Stevension, 1959). The C:N ratio was calculated by dividing the percentage of carbon with the percentage of nitrogen.

Statistical analysis

One-way analysis of variance (ANOVA) was used for analyzing the variation in the population dynamics of earthworms (total density and biomass) and various soil properties from different habitats of Cauvery delta areas. Also correction co-efficient was used to examine the relationship between various soil parameters and earthworm population dynamics in different habitats of Cauvery delta areas.

RESULTS AND DISCUSSION

In general, relatively higher population dynamics of earthworms are found in the WLCA than DLCA of different sites (S1 – S12) of Cauvery delta taluk of areas. Among the five different pedoecosystems, more earthworm density and biomass are found in the paddy, followed by sugarcane, banana, groundnut and coconut field, respectively (Table 2). Among the five pedoecosystems, only two type of soil are found (namely sandy loam and clay loam). A significantly optimal and favourable soil physico-chemical and biological parameters like moisture, temperature, pH, organic carbon, total nitrogen, C:N ratio, available phosphorus, available potassium and microbial activity are found in the WLCA (paddy> sugarcane> banana field) than DLCA (groundnut> coconut) (Table – 3). Also correlation co-efficient of relationship between various soil ecological parameters and earthworms population dynamics in different pedoecosystem are also found (Table – 4 & Figure -2).

Soil functions to sustain crop productivity, maintain environmental quality and support animal and plant life as well. Natural soils are comprised of soil particles of varying sizes [sands (0.05-2.0 mm), silts (0.002-0.05 mm) and clays (<0.002 mm)]. The relative proportions of soil separates–sands, silts and clay in a particular soil determine its soil texture and type. Soil texture plays an important role in earthworm distribution (Huerta et al., 2007). A significant relationship were observed between clay and silt soil with earthworm distribution in a temperate grass-cover field (Nuutinen et al., 1998) and earthworm density and soil clay content in rain forest and areas used for forestry (Huerta et al., 2007). Also an inverse relationship between soil sand content and earthworm abundance was observed in a tropical pasture system (Huerta, 2002). In the present our field study of soil from five different habitats of Cauvery delta areas are found to observed only two types of soils - sandyloam and clayloam and this type of soil variation in the study areas are due to the nature of earlier agricultural activity and the nature of soil texture. In general, a number of ecological factors are known to play a vital role in the population dynamics of earthworms in the soil. The most important among them are moisture, temperature, organic carbon, hydrogen ion concentration and soil texture. The present investigation in the delta taluk areas reveals that the clayloam and sandyloam soils with an optimal and ideal moist (17.6 – 23.8%), pH (6.7 – 7.3), neutral soil, OC content (0.61-78%) and temperature (17.3-18.5 C), appear to be favourable for maximum population dynamics of earthworms.

Population dynamics of earthworm in soil was reported to be determined by the soil type (Decaens et al., 2004), quality and quantity of organic matter added to the soil (Edwards and Bohlen, 1996). The type of species and density of earthworms determines the biomass. Growth rates of earthworm might have been enhanced by the higher food intake. It has been suggested that earthworms with more food availability gain weight than those with little or no supplementary food (Muldowney et al., 2003). Eriksen – Hamel and Whalen (2006), Parthasarathi and Ranganathan (2000) and Parthasarathi (2010) pointed out that increased soil moisture, favourable temperature and better microbial activity result in significant increased in growth rate of earthworms. In general, earthworms have the capacity to utilize soil microbes as their food (Flack and Hartenstein, 1984; Ranganathan and Parthsarathi, 1999). Growth and reproduction in earthworm require C, N and protein and these were obtained from letter, grit and microbes (Edwards and Bohlen, 1996; Parthasarathi and Ranganathan, 2000; Parthasarathi, 2010). Earthworm density and biomass vary among the cultivable soils. In the present study, WLCA (paddy > sugarcane > banana field) harbor maximum population dynamics of earthworms whereas population dynamics are low in DLCA (groundnut > coconut field). This may be due to the influence of better and favourable edaphic factors like OC, N and moisture content that play a significant role in population dynamics of earthworms. In addition to these, more microbial populations are found in the WLCA than DLCA. The microbes form as a protein food for earthworms and these edaphic factors and microbes synergistically (figure - 2) involved in order to influence the density and biomass of earthworms at maximum in the different pedoecosystem of Cauvery delta areas.

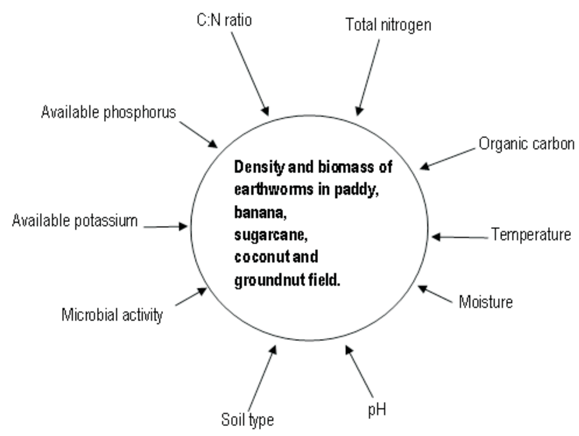

Figure 2. Schematic representation of population dynamics of earthworms in different pedoecosystem of Cauvery delta areas with references to different soil ecological parameters

Earthworm activity depends upon adequate availability of soil moisture (besides other factors) but not all species have the same moisture requirement and within a species the moisture requirement for earthworm population from different regions of the world can be quite different (Edwards and Bohlen, 1996). Because of their cutaneous respiration and excretion of nitrogen as ammonia, a moist environment is essential for maintenance of their life process. The population dynamics of earthworms in the two different cultivable land area of five different pedoecosystems of Cauvery delta areas in the present study are found in soil having 17.6-23.8% ranges of moisture content and among the five different study habits significantly more moisture content and more earthworm population dynamics are found in the paddy, followed by the sugarcane, banana, groundnut and coconut field. This is due to the adequate and frequent irrigation, better water holding capacity of soil, higher microbial population and activity, OC, N and other nutrient content of the soil. Lavelle et al. (1987) reported occurrence of maximum population of earthworms within a soil moisture range of 40-50% beyond the level of which their population declined. Also, both positive and negative correlation ($P<0.05$) of earthworm density and biomass with soil moisture content in the different pedoecosystem of Cauvery delta areas are found in the present study. A positive correlation between earthworm dynamics and the percentage of soil moisture content have been reported by many workers (Tian et al., 2000; Bisht, et al., 2003; Tripathi and Bhardwaj, 2004; Lalthanzara, et al., 2011; Najar and Khan, 2011 and Chaudhuri and Nath, 2011). The activity, metabolism, growth, respiration and reproduction of earthworms are all influenced greatly by temperature. Most of the earthworm species (77%) occur in the soil with 24 to 28C temperature range. No earthworm species are found above 30C soil temperature. Absence of earthworms in very high soil temperature (>30C) is probably due to their inability of respiratory exchange to maintain adequate oxygen supply to the tissue as metabolic rate increases with increase in the temperature (Lee, 1985). According to Edwards and Bohlen (1996) optimum temperature for typical earthworms is 18-25C. In the present study of five different pedoecosystems are found in soil having 17.3 to 18.5C ranges of temperature. This indicate the ideal and optimal soil temperature for earthworm survival and reproduction in these areas. And among the five different study field soil, temperature variations are also found (paddy<banana< sugarcane< coconut< groundnut) which are due to the seasonal variation of agricultural activity and irrigation and also the water holding capacity of the soil and slow evaporation of soil water. Temperature largely affects activity of earthworms in temperate regions. Tropical species can withstand higher temperatures. Curry (1998) opined that on a global scale, temperature is the climatic variable of greatest significance, because it determines metabolic rates and the diversity of food resources. Temperature shows a significant positive and negative ($P<0.05$) correlation with earthworm density and biomass in the different pedoecosystems of Cauvery delta areas, in the present study. The studies on fallows made by Tian et al. (2000), Bishat et al. (2003), Tripathi and Bhardwaj (2004), Chaudhuri and Nath (2011), Lalthanzara et al. (2011) and Najar and Khan (2011) suggest that earthworms density and biomass are positively correlated with soil temperature.

Soil pH, in general, acts as a limiting factor on earthworm distribution. Most of the earthworms are neutrophilic, preferring a pH of 6.0-7.0 and the species diversity is drastically reduced at pH > 7 except for tolerant species, which may be due to the fact that soil with pH considerably higher than 7 are mostly semiarid or arid and are favourable for earthworms (Sathianarayanan and Khan, 2006). In the present study of different pedoecosystem of Cauvery delta areas, the population dynamics of earthworms are found within a narrow range of pH (6.7 – 7.3) and there is a variation of soil pH within these delta areas are due to the variation of salinity and acidity nature of the soil. As soil pH is related to other factors that have an important influence on earthworm population (eg. clay content, cation exchange capacity), it is often difficult to establish the direct cause and effect relationship between the soil pH and size of the earthworm population (Edwards and Bohlen 1996; Edwards et al., 2011). A significant of both positive and negative ($P<0.05$) correlation are observed between soil pH and earthworm density and biomass in the different pedoecosystems of Cauvery delta areas, in the present study. Studies have shown that high earthworm dynamics is associated with soil pH (Tian et al., 2000; Bisht et al., 2003). A positive correlation between earthworm density and biomass with the soil pH have been reported by many workers (Tripathi and Bhardwaj, 2004; Najar and Khan, 2011; Chaudhuri and Nath, 2011 and Lalthanzara et al., 2011).

Organic matter (which includes OC, macro and micro nutrients) is very essential for soil organisms and soil health. The deficiency in OC reduces storage capacity of soil N, P, S and reduction in soil fertility (Kale, 1998). Kale (1998) reported that abundance and diversity of earthworm species is affected by OC and N content of the soil. A positive correlation between earthworm density and biomass and the percentage of soil OC have been reported by many workers (Tian et al. 2000; Brown et al., 2003; Liu et al., 2004 and Lalthanzara et al. 2011). The higher occurrence of maximum density and biomass of earthworms in the present study, at WLCA as compared to DLCA is supported by higher moisture (19.3 to 23.8%)/ OC (62-69%)/ N (0.28-0.33%) and microbial activity (1.85 – 2.18 l/H/5g of substrates) of the soil. Significant positive and negative correlations are obtained between the density and biomass of earthworms with OC in the soils of different pedoecosystems, in the present study. This is consistent with previous research that established correlation between population dynamics of earthworms and OC (Edwards and Bohlen, 1996; Hendrix et al., 1992; Sinha et al., 2003; Najar and Khan, 2011 and Feijoo et al., 2011).

Nitrogen, one of the soil edaphic factor play a significant role in abundance and distribution of earthworms. Edwards and Lofty (1972) have reported that earthworm activity is influenced by the soil physico-chemical and biological parameters besides feed. Among the two different cultivable land areas, in the present study, WLCA are found to shows more N content than DLCA. This is due to the naturally available nutrient contents of the soil/ optimal moisture/ soil input of organic materials during agricultural activity/ enhanced nutrient mineralization by the earthworm–microbe symbiosis (Parthasarathi, 2010) and enhanced microbial activity. Earthworm need the usual major and minor nutrients required for cell development. They require C, N, P and S in organic form as protein and amino acids (Syers and Springett, 1983). Similar findings have been reported by Parthasarathi and Ranganathan (2000) and Lalthanzara et al. (2011). In the present study, it is found that nitrogen has a significant positive and negative correlation between earthworm density and biomass. This result suggests that in the different pedoecosystems the nitrogen alone may not be so important in governing the earthworm; rather C:N ratio and other physico-chemical and biological parameters are more influential. Influence of various soil parameters on earthworm population is also reported (Sathiyanarayananan and Khan, 2006; Lalthanzara et al., 2011 and Feijoo et al., 2011).

The availability of adequate OC and N in assimilate form is essential for the survival and growth of organisms in soil (Lee, 1985). Absolute deficiency of one or both elements some times limits earthworm population in soil. According to Kale and Krishnamoorthy (1978), the abundance of earthworms and their population diversity are greatly influenced by C:N ratio and the ratio of humic acid to felvi acid (H:F) of the soil. Kale (1998) reported that abundance and diversity of earthworm species is affected by carbon and nitrogen content of the soil. It is probable that quality of organic mater (C:N and H:F) along with preferential measured extremes of organic matter are important determinants of the distribution, abundance and diversity of earthworms (Chaudhuri et al., 2008). In the present study, the C:N ratio recorded in WLCA ranges from 2.09 to 2.21 and in DLCA ranges from 2.7 to 4.9. This indicate the adequate level of OC and N in the soils of different pedoecosystem that support for the survival, distribution, abundance and density of earthworms in the Cauvery delta areas. Also in the present study, the C:N ratio showed significant positive correlation with earthworm density and biomass in the paddy, coconut and groundnut fields and in negative correlation with the earthworm density and biomass in the banana and sugarcane fields. Similar studies have shown that earthworm density and biomass is positively associated with C:N ratio(Kale, 1998; Sathyanarayanan and Khan, 2006 and Feijoo et al., 2011) and negatively associated with high C:N ratio (Lalthanzara et al., 2011).

Phosphorus is the second most abundant nutrient in soil organic matter and it is richly contained in the microbial tissue about 2% of dry weight (Ranganathan, 2006). In the present study, the available phosphorus value of soils are recorded from 24.66–26.39 kg.ha-1 in WLCA and it ranged between 21.18 – 23.55 kg.ha-1 in DLCA. The enhanced availability of available phosphorus in WLCA than the DLCA is due to the enhanced mineralization process by earthworm – microbe (Parthasarathi, 2010)/ soil input of organic materials during agricultural activity/naturally available nutrient content of soil/optimal moisture and microbial activity. Phosphorus shows a significant positive and negative correlation with earthworm density and biomass of different pedoecosystem of Cauvery delta areas. Bisht et al. (2003) and Lalthanzara et al. (2011) observed a coincidence of positive correlation between available phosphorus and earthworm density and biomass in agroforestry ecosystems and various cultivable soils. Similar observations were made by many researchers (Nana-Osei, et al., 2008 and Najar and Khan, 2011). The studies on follows made by Parthasarathi and Ranganathan (1999), Tian et al., (2000), Suarez et al. (2003), Parthasarathi (2007) and Parthasarathi (2010) suggest that earthworm significantly increased the amount of available and exchangeable phosphorus in the soil.

In soil, potassium exists as a component of soil minerals, fixed potassium, exchangeable and water soluble (Ranganathan, 2006). Available potassium in soil ranged between 79.65 – 88.12 kg.ha-1 in WLCA while it is from 74.76 to 76.48 kg.ha-1 in DLCA of Cauvery delta district in the present study. More available potassium in the WLCA than DLCA in the present study is due to the enhanced role of earthworm – microbes during mineralization process (Parthasarathi, 2010) optimal moisture, soil input of organic material during agricultural activity, naturally available nutrient content of the soil / enhanced microbial activity. Also, in the present study, both positive and negative correlation ($P<0.05$) of earthworm density and biomass with soil available potassium in the different pedoecosystem of Cauvery delta areas are found. Reddy and Pasha (1993) and Nana-Osei et al. (2008) observed a coincidence of the peak level of available potassium and high earthworm density and biomass. Similar observations of both positive and negative correlation between earthworm biomass and density with available potassium were reported in two different agroforestry systems (Lalthanzara et al., 2011). On the contrary, Bisht et al. (2003) reported no such correlation between soil available potassium and earthworm density and biomass.

In soil, the dehydrogenase activity is an index of microbial activity; the activity directly correlated mostly to the microbial population. Among the two different cultivable land areas, in the present study, more microbial activity are found in the WLCA (paddy > sugarcane > banana) than DLCA (groundnut > coconut). This is due to the presence of optimal moisture, more OC, N and microbial population. In the present study, a significant positive correlation coefficient of the relationship between population dynamics of earthworms and microbial activity in the different pedoecosystems of Cauvery delta areas, except biomass in banana, sugarcane and groundnut field and density in banana and groundnut field where the biomass and density of earthworm are negatively correlated with the microbial activity. A correlation between earthworm abundance and distribution and microbial activity and microbial population was reported by other workers (Scheu, 1987; Mulongoy and Bedoret, 1989). Nana-Osei et al. (2008) reported a positive correlation between population dynamics of earthworms and soil microbial activity. Williams et al. (2006), Parthasarathi et al., (2007) and Parthasarathi (2007, 2010) observed that earthworms sustained and transported microbes in soil and vermicomposts suggesting a mutualistic relationship between earthworms and microbes.

In soil, the edaphic factors – OC, N and moisture play a significant role in abundance and distribution of earthworms (Najar and Khan, 2011). Earthworms, for the growth and reproduction, have been shown to meet their nutritional requirement by feeding on organic matter and microbes (Edwards and Bohlen, 1996; Parthasarathi and Ranganathan, 2000). Earthworm have been shown to be microbivorous (Flack and Hartenstein, 1984; Edwards and Bohlen, 1996; Ranganathan and Parthasarathi, 1999; Parthasarathi, 2010). In addition to the edaphic factors, microorganisms also act as a N and protein food support growth and reproduction of earthworms and thereby these are involved together influence the maximum density and biomass of earthworms in the Cavuvery delta areas. In conclusion, it may be suggested from the present study that the synergistic effect of soil physico-chemical and biological parameters (figure – 2), even though both positively or negatively correlated with each others of different pedoecosystems of Cauvery delta areas had more influence on population dynamics of earthworms.

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Table - 1. Density and biomass of earthworms in different habitats under tropical / subtropical climatic conditions

Habitat	Density ($no.m^{-2}$)	Biomass ($g.m^{-2}$)	Site	Extraction method	References
Different cultivable land areas – paddy, banana, sugarcane, coconut and groundnut field	53-163	36.56-272.61	Cauvery delta districts, Tamil Nadu (India)	Digging and hand sorting	Present study
Moderately degraded natural forests, highly degraded natural forests, rehabilitated forest land, traditional pure crop system, traditional degroforestry system and ahandored agricultural land and rehabilitated agricultural land	5-147	11-266	Central Himalaya (India)	Hand sorting	Bhadauria *et al.* (2012)
Deciduous rubber plantation (Subtropical)	108.56	43.37	Tripura (India)	Digging and hand sorting	Chaudhuri and Nath (2011)
Natural forest and plantations (20 years old)	12.43-386.22 & 6.65-19.20	12.43 & 4.74-15.24	Caspian (Iran)	Digging and hand sorting	Kiasari *et al.* (2009)
Different ecosystems – teak forest, home garden and fallow paddy	1790-2940	309-961	Central Java (Indonesia)	Hand sorting	Widyastuti (2004)
Pine forest (6 year old)	65	1-40	Central Himalaya (India)	Hand sorting	Bhadauria *et al.* (2000)
Mixed forest	149	4.1	Central Himalaya (India)	Hand sorting	Bhadauria *et al.* (2000)
Acacia plantation	200	9.67	Western Ghat (India)	Hand sorting	Blanchart & Julka (1997)
Forest	160.5	27.92	Western Ghat (India)	Hand sorting	Blanchart & Julka (1997)
Rubber plantation (20 yrs)	150.4	59.5	Cote d' Ivoire	Hand sorting	Gillot *et al*. (1995)
Reserve forest	72.64	9.77	Tamil Nadu (India)	Digging and hand sorting	Ismail *et al.* (1990)
Tropical rain forest	80-121	34.2-42.4	Mexico	Hand sorting	Fragoso & Lavelle (1987)
Tropical rain forest	64-166	3.3-22.7	Malaysia	Hand sorting	Leaky & Proctor (1987)
Plain grassland	322	58.74	Karnataka (India)	Hand sorting	Krishnamoorthy (1985)
Deciduous forest	24-131	7.0-28.5	Orissa (India)	Digging and hand sorting	Mishra & Dash (1984)
Grazed upland pasture	75-272	12-70	Orissa (India)	Hand sorting and wet sieving	Senapati & Dash (1981)
Tropical savana	230	49	Ivory Coast	Hand sorting and wet sieving	Lavelle (1974)

Chaudhuri et al. (2008), Chaudhuri and Nath (2011), Bhadauria et al., (2012).

Table 2. Population dynamics of earthworm in Cauvery delta areas* from different habitats (n=6) (P<0.05)

Localities *	Paddy field Density ($Ind. m^{-2}$)	Paddy field Biomass ($g.m^{-2}$)	Banana field Density ($Ind. m^{-2}$)	Banana field Biomass ($g.m^{-2}$)	Sugarcane field Density ($Ind. m^{-2}$)	Sugarcane field Biomass ($g. m^{-2}$)	Coconut field Density ($Ind. m^{-2}$)	Coconut field Biomass ($g. m^{-2}$)	Groundnut field Density ($Ind. m^{-2}$)	Groundnut field Biomass ($g. m^{-2}$)
Aarpakkam (S_1)	18	30.06	8	9.2	15	21.3	4	2.72	5	4.05
Kunnam (S_2)	14	23.38	7	8.05	11	15.62	4	2.66	7	5.67
Pazhaiyapalayam (S_3)	13	21.71	6	6.19	8	11.36	3	2.30	6	4.86
Sembadhaniruppu (S_4)	9	15.03	5	6.4	6	8.52	4	2.59	5	4.35
Manikiramam (S_5)	21	35.07	10	11.89	17	24.14	5	3.41	7	5.35
Aharaperunthottam(S_6)	12	20.04	8	10.4	11	14.76	4	2.61	4	3.66
Marudangudi (S_7)	11	18.37	5	6.2	7	9.55	6	4.08	9	7.29
Mudalaimedu (S_8)	17	28.39	9	11.01	13	18.46	5	3.68	6	4.75
Nangur (S_9)	13	20.31	7	7.98	10	14.10	5	3.28	7	5.44
Kadiramangalam (S_{10})	14	23.13	8	9.8	11	14.87	6	4.21	8	6.48
Koothiyampettai (S_{11})	13	22.11	8	10.2	12	17.04	4	2.70	5	4.13
Natham (S_{12})	8	15.01	6	7.4	7	9.32	3	2.32	7	5.80
Total ($\bar{X}$ ±)	**163**	**272.61**	**87**	**105.43**	**128**	**179.04**	**53**	**36.56**	**76**	**61.83**

ANOVA (Analysis of variance - one way)

	Total density	Total Biomass
Between groups		
X	53748.0	220474.87
Y	1010.0	1.149
Within groups		
X	13437.0	55118.717
Y	40.4	4.595
F – value	332.599	1199502

X – Sum of squares, Y – Mean of squares

* Under Sirkazhi taluk of Nagapattinam district, Tamil Nadu

state.Table 3. Soil properties of Cauvery delta areas* from different habitats (n=6) (P<0.05)

Habitats	Soil type	Moisture (%)	Temperature (?C)	pH	OC (%)	N (%)	C/N ratio	P ($kg.ha^{-1}$)	K ($kg.ha^{-1}$)	Microbial activity [a]
Wet land cultivable areas										
Paddy field	Sandy loam	23.8	18.5	6.8	0.69	0.33	2.09	26.39	88.12	2.18
Banana field	Sandy loam	22.5	18.2	6.7	0.62	0.28	2.21	24.66	79.65	1.85
Sugarcane field	Clay loam	19.3	17.8	6.9	0.66	0.31	2.12	25.16	83.42	1.96
Dry land cultivable areas										
Coconut field	Clay loam	17.6	17.4	7.1	0.78	0.16	4.9	21.18	74.76	1.79
Groundnut field	Sandy loam	18.7	17.3	7.3	0.61	0.23	2.7	23.55	76.48	1.82

ANOVA (Analysis of variance one way)

Between groups									
X	62.449	57.847	19.891	0.105	0.028	8.265	222.155	1340.290	2.977
Y	31.225	28.924	9.945	0.052	0.014	4.133	111.077	670.145	1.489
Within groups									
X	88.348	28.924	2.840	0.138	0.035	8.460	44.606	172.100	0.795
Y	7.362	3.366	0.237	0.011	0.003	0.705	3.717	14.342	0.066
F – value	4.241	8.593	42.017	4.576	4.847	5.862	29.883	46.727	22.479

X – Sum of squares, Y – Mean of squares

* Under Sirkazhi taluk of Nagapattinum district, Tamil Nadu state

a µl H/5 g substrates (dehydrogenase activity)

Table 4. Correlation co-efficient (r) of earthworm density (Ind. m-2) and biomass (g.m2) with soil properties from Cauvery delta areas

Soil properties	Paddy field Density ($Ind. m^{-2}$)	Paddy field Biomass ($g. m^{-2}$)	Banana field Density ($Ind. m^{-2}$)	Banana field Biomass ($g. m^{-2}$)	Sugarcane field Density ($Ind. m^{-2}$)	Sugarcane field Biomass ($g. m^{-2}$)	Coconut field Density ($Ind. m^{-2}$)	Coconut field Biomass ($g. m^{-2}$)	Groundnut field Density ($Ind. m^{-2}$)	Groundnut field Biomass ($g. m^{-2}$)
Moisture (%)	-0.311	0.100	0.247	-0.299	0.348	-0.891*	-0.458	0.364	0.460	-0.094
Temperature (?C)	-0.827	0.302	-0.335	0.027	0.872*	-0.810	-0.628	0.653	0.311	-0.461
pH	-0.768	0.313	0.354	0.666	0.482	0.509	-0.658	0.589	0.623	-0.494
Organic carbon (%)	0.411	-0.885*	0.056	0.321	-0.528	-0.355	0.032	0.132	-0.336	0.469
Nitrogen (%)	0.751	-0.341	-0.554	0.468	0.158	0.680	-0.081	0.531	0.240	-0.424
C/N ration	0.579	0.019	-0.329	-0.438	-0.117	-0.567	0.221	0.250	0.223	0.187
Phosphorus ($kg. ha^{-1}$)	0.005	-0.273	0.552	0.023	-0.062	-0.162	0.215	-0.559	-0.821*	0.323
Potassium ($kg. ha^{-1}$)	-0.102	-0.503	0.569	-0.341	-0.045	0.034	-0.332	-0.475	0.362	0.097
Microbial activity [a]	0.107	0.461	-0.447	-0.001	0.168	-0.100	0.309	-0.399	-0.660	0.319

* Level of significance at P<0.05, '-' decreasing level

a µ l H/5 g substrates (dehydrogenase activity)