Impact on the soil from fertilisers and pesticides.

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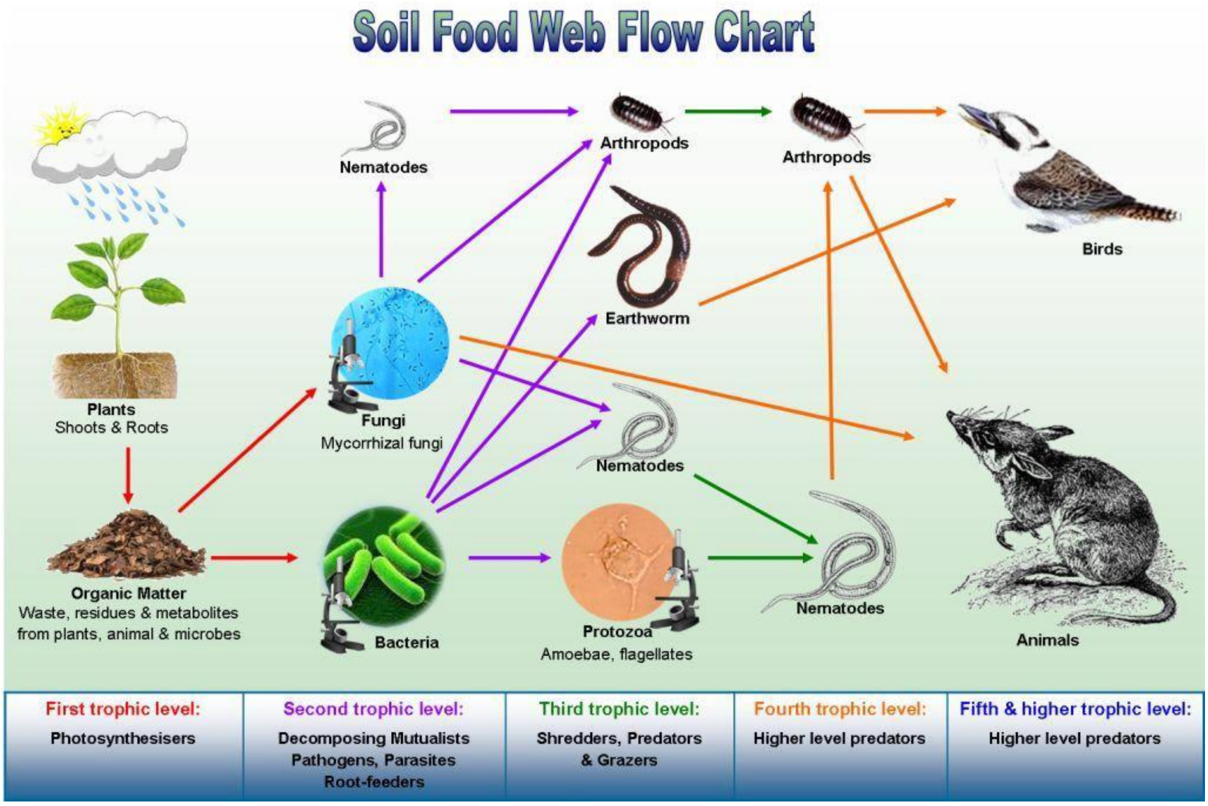
Dirt (sand, silt and clay) becomes soil with the addition of organic matter and microbes. More than 90% of all life on earth resides underground in the form of bacteria, fungi, nematodes, protozoa, arthropods, and more (see Australian Soil Food Web with earthworms).



(Adapted from Soil Biology Primer, USDA Natural resources Conservation Service).

Although farmers understand their soil and understand the importance of maintaining it in good health, they receive conflicting messages from suppliers of input products that are supposed to improve productivity, reduce disease pressure and extend the growing season.

A limiting resource in agriculture around the world is access to sufficient water to produce the food required to feed an increasing population estimated to increase by another 2 billion by the year 2050 with a global food demand around 70% greater than it is today (Fraley, 2014).

Literature is also conflicting on the impact of the input chemicals on the soil biota. However, there is an acknowledgement that soil microbes do have a role in soil and plant health. Pesticides, herbicides, fungicides, fertilisers can migrate into dams and rivers where they become a public health and environmental issue. These same chemicals cause ground water contamination, eutrophication, algal blooms and acid rain. The industrialisation of agriculture has increased the chemical burden on natural ecosystems such that many are now broken or functioning sub-optimally (Nicolopoulou-Stamati 2016). Soil organisms have an important role in the above ground community dynamics so any influence on the terrestrial ecosystem may affect the below ground ecosystem (Morrien *et al* (2017).

The term pesticide covers compounds including insecticides, fungicides, herbicides, rodenticides, molluscicides, nematicides, plant growth regulators and more. The use of these chemicals has increased agricultural production. But negative impacts of these chemicals have increased at the same time. There is damage to land structure in agriculture, fisheries, fauna and flora through loss of beneficial predators and increased virulence of agricultural pests. Increased mortality and morbidity of humans has been recorded especially in developing countries (Wilson & Tisdell, 2001). These authors, including Aspelin (1997) also suggest that the current conventional agricultural system “locks in” farmers in a system of pest control technology that results in their reliance on the synthetic, but ultimately non-sustainable, technology.

Reporting of effects on soil biota in the scientific literature is variable. Impacts are seen to be positive and negative. This is obvious when considering the number of organisms and the diversity of functional groups, the number of products available for use, the manner in which they are applied and the different environments in which they are used.

Microbial populations change with seasons, in relation to the last rain event, soil temperature, soil chemistry, soil pH, prevalence of food source, nutrient levels in the soil and plant, depth at which the sample was taken, formulation and rate of application of fertilisers, and pesticides (Gupta, 1994). A review paper by Pal et al (2006) suggested that most pesticides applied at field application rate did not have a lasting impact on soil biological parameters. The degree of biodegradability depends on the chemical structure of the particular pesticide and also on the physiochemical properties of the soil. A further aspect is the total microbial biomass in the soil.

The continuous application of pesticides in agriculture may lead to an accumulation in the ecosystem resulting in a negative impact on the environment and humans and production animals. Variables in agriculture around the world are so great that the combination of degradation events through microbial degradation, chemical hydrolysis, photolysis, leaching and surface runoff will be different from soil to soil and season to season. Impact of pesticides on soil biota must be considered for all applications (Lynch, 1995). Soil microbial populations are affected by pesticide application, both qualitatively and quantitatively, by the direct impact of the applied pesticide on the target microbial species (Matsumara & Boush, 1971). By contrast, investigations by Hart & Brookes,(1996b) showed that the use of five pesticides (Benomyl, Chlorfenvinphos, Aldicarb,Ttriadimefon and Glyphosate) over 19 years of accumulative annual field application, either used singly or in combination, had no measurable long-term harmful effects on the soil microbial biomass.

Captan and Thiram are shown to cause deceases in microbial biomass (Anderson, 1981) but the effect was short term. Duah-Yentumi & Johnson (1986) showed that repeated application of Carbofuran significantly reduced microbial biomass. Vinclozolin application had a dramatic impact on the fungal component of the microbial biomass. Iprodione had less obvious effects and MCPA and Simazine had no detectable effect on the microflora. However, repeated application of Paraquat significantly lowered the fungal biomass. They determined that single or repeated applications of these chemicals produced substantially variable effects on the soil microbial biomass. Wardle & Parkinson (1990b) applied glyphosate and 2, 4-D at field application rates to tilled field plots and tested after 45 days. They found that Glyphosate temporarily enhanced the bacterial population and actinobacteria and fungal populations were not affected. Their conclusion was that Glyphosate had no negative effect on soil microbial populations and 2, 4-D effect was transient.

In researching the literature, it is apparent that many of the studies on the impact of various pesticides, in particular herbicides, were carried out under controlled laboratory conditions. Laboratory studies rarely translate or reflect field conditions so many important parameters are not considered in the studies. What happens in problem soil, for example, acid sulphate soils or flooded soils? The studies do not consider the diverse and complex microbial communities in the environment.

Other researchers used respiration as a method to determine the impact of pesticides on microbial health. Actively living cells require a constant supply of energy generally obtained from transforming/decomposing organic matter. So the metabolic activities of soil microbes can be quantified through the evolution of CO_2. Several studies investigated the effects of 2,4-D, Picloram and Glyphosate on soil respiration and found that Picloram and 2,4-D temporarily depressed respiration and Glyphosate briefly enhanced respiration (Wardle & Parkinson, 1990a; Wardle & Parkinson, 1991; Araujo *et al,* 2003). Zelles *et al* (1985) investigated over 48 days the effect on soil respiration of herbicides (Atrazine, Pentachlorophenol, 4-Chloroaniline and Chloroacetamide), fungicides (Zineb and Captan), insecticides (Lindane and 4-Notrophenol) and bactericides (Mercuric chloride). Results suggested that Atrazine, Lindane and Captan had little effect on soil respiration but the other pesticides had a considerable effect on microbial respiration. They then found that addition of organic matter in the form of alfalfa/lucerne meal assisted in reversing of impact of the pesticides on the soil microbial populations.

Increasing soil organic matter is seen to alter the way in which pesticides function in soil. Soil organic matter may either increase or decrease the degradation by microbes of pesticides by stimulating pesticide adsorption processes or increase microbial activity (Perucci *et al,* 2000; Walker, 1975; Nair & Schnoor, 1994). When soil microbial biomass is discussed, it is defined as the part of organic matter in soil that constitutes living microbes less than 5-10 cubic micrometers such as bacteria, actinobacteria, algae, protozoa and micro fauna. Thus, this does not consider fungi or earthworms (Sparling, 1985).

More recent research is examining the possible relationship between Glyphosate, genetically modified crops and health problems in the USA. Correlation analyses have raised concerns about possible connections between Glyphosate use and health issues such as hypertension, diabetes, strokes, autism, kidney failure, Parkinson's disease, Alzheimer's diseases, and cancer (Kwaitkowska *et al*, 2014) and the ability of Glyphosate to cause gluten intolerance which is associated with deficiencies in essential trace elements and increased risk in developing non- Hodgkin's lymphoma (Samual *et al,* 2009).

Swanston *et al* (2014) and others have shown that Glyphosate can display endocrine-disrupting activity, affect human erythrocytes *in vitro,* and possibly cause extreme disruption in the shikimate pathway which is a major pathway found in plants and bacteria and humans (Samual *et al* 2015); Clair *et al,* 2012).

Many parameters are used to study the impact of pesticides on soil ecology both in the field and in laboratory studies. Most studies showed that pesticides used at label rate have little long tem effect on microbial biomass. However, microbial community structure may be changed even if the overall population of the community remains apparently unaffected by a pesticide. Bacterial populations relative to fungal population, for example, may change. The diversity of the populations in particular ecological niches may alter. Literature is poor in detail related to microbial diversity. Figure A shows a quantitative analysis of soil biota from a conventional chemical input farm and Figure B is the same soil 18 months later as it transitions to biological/organic inputs only.

Figure A Quantitative analysis of soil biota from a conventional farming system using synthetic fertilisers, and various pesticides. Protozoa, fungi, mycorrhizal fungi and nematodes are all affected by the inputs. Plant available Nitrogen availability is low (56-64kg/ha).

Soil Biology Analysis

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Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		0.760	13.3	47.1	7.43	294	3
Comments		In Good Range	In range	Below range	Below range	Below range	
Expected Range	Low	0.45	10	50	25	500	
	High	0.85	15	200	50	2000	

		Protozoa (Numbers/g)			Total	Mycorrhizal Colonization (%)	
		Flagellates	Amoebae	Ciliates	Nematodes #/g	ENDO	ECTO
Results		**201**	**736**	101	**3.43**	**5%**	**0%**
Comments		Low	Low	High	Low	Low	Low
Expected Range	Low	20000	20000	50	50	40%	40%
	High			100	100	80%	80%

Organism Biomass Ratios		Total Fungal to Tot.Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Act.Bacterial	Plant Available N Supply (kg/ha)
Results		6.23	**0.03**	0.28	**0.56**	56-84
Comments		Good	Low	Good	Low	
Expected Range	Low	5	0.25	0.25	2	
	High	10	0.95	0.95	5	

Nematode detail (# per gram or # per mL)
Classified by type and identified to genus.
(If section is blank, no nematodes identified.)

Bacterial Feeders		
Bacterial Feeder		2.08
Root Feeders		
Root Feeders		0.52

Figure B show the same farm as it transitioned to the biological/organic system over 18 months. Protozoa, fungi, mycorrhizal fungi, nematodes are increasing with time. The plant available nitrogen is now more than is required for the crop (336+kg/ha).

Soil Biology Analysis

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Organism Biomass Data		Dry Weight	Active Bacterial (µg/g)	Total Bacterial (µg/g)	Active Fungal (µg/g)	Total Fungal (µg/g)	Hyphal Diameter (µm)
Results		0.660	65.0	87.9	4.97	170	3.5
Comments		In Good Range	Above range	Below range	In range	Below range	
Expected Range	Low	0.45	1	175	1	175	
	High	0.85	5	300	5	300	

		Protozoa (Numbers/g)			Total	Mycorrhizal Colonization (%)	
		Flagellates	Amoebae	Ciliates	Nematodes #/g	ENDO	ECTO
Results		4192289	53980	87	**3.02**	**23%**	**0%**
Comments		High	High	Good	Low	Low	Low
Expected Range	Low	5000	5000	50	10	40%	40%
	High			100	20	80%	80%

Organism Biomass Ratios		Total Fungal to Tot.Bacterial	Active to Total Fungal	Active to Total Bacterial	Active Fungal to Act.Bacterial	Plant Available N Supply (kg/ha)
Results		1.93	**0.03**	0.74	**0.08**	336+
Comments		High	Low	High	Low	
Expected Range	Low	0.8	0.15	0.15	0.75	
	High	1.5	0.2	0.2	1.5	

Nematode detail (# per gram or # per mL)
Classified by type and identified to genus.
(If section is blank, no nematodes identified.)

Bacterial Feeders		
Bacterial Feeder		1.36
Fungal Feeders		
Fungal Feeder		0.21
Root Feeders		
Root Feeders		0.43

There is an urgent need for standardisation in handling soil samples for these toxicity studies and it is very well known that the soil microbial community in the field is very different from that in pot and laboratory studies. Long term effects on non-target organisms must be considered in future studies,

That crops feeding the world's increasing population requires protection is a given. Modern agriculture has to deal with increased population, food security, health risks from pesticides, pesticide resistance, degradation of the world's soils and environments and climate change. The health and environmental effects of chemical pesticides must be taken into consideration which means a dramatic reduction in the application of chemical pesticides and consideration of a smarter method of producing food with more consideration of the soil microbial populations. Developing pesticide-free zones and implementing a total ban on pesticides in urban green areas is achievable. Encouraging local urban gardening is already happening and must be further encouraged. Considering soil health as the pathway to nutrient dense food that is positive to the gut biome means less food needs to be produced not more. Using agricultural land more efficiently will feed the global population; reduce food waste and encourage agricultural around the urban boundaries will go a long way to minimising chemical pesticide use.

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