Working with our friends in the soil

A farmer’s guide to life in the soil
June 2009
Photos and illustrations used in this booklet were provided by members of the ACIAR team unless otherwise acknowledged.

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This booklet was produced by NSW DPI, BPTP NAD and the Indonesian Soil Research Institute staff with input from Aceh farmers and PPL staff.

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Indonesian Soil Research Institute
Indonesian Centre for Rice Research

Australia Indonesia Partnership for Reconstruction and Development
Program Kemitraan Australia Indonesia untuk Rekonstruksi dan Pembangunan
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Preface

Soil is full of living organisms that will keep the soil healthy if you look after them.

This guide will show you:
- what the organisms do in the soil
- how their activities help farmers
- what farmers can do to keep them in the soil.

Some organisms in the soil are so small you cannot see them. These include bacteria, fungi, nematodes and protozoa. They are known as microorganisms and they comprise 80-90% of all life in the soil. In a teaspoon of healthy living soil there can be millions, even billions, of microorganisms.

Some soil organisms are just big enough to see. These include ants, termites, collembola and mites.

Some organisms are so big you can see them easily. These include earthworms, spiders, beetles, snails.

It is interesting to know what is living in the soil, but for farmers it is more useful to know what these organisms do in the soil and how they can help production.
Types of soil organisms

*based on concept by Dr Daniel Dindal, 1978*
### A: Activities of soil organisms and their benefits to farmers

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1. Soil organisms move through the soil and mix it around

Many of the larger organisms living in the soil burrow into it and move it around. These organisms include earthworms, dung beetles, ants, termites, and larger animals such as land crabs, mice and rats. They move soil to the surface and take organic matter (eg manure) down into the soil.

Benefits
The organic matter they bring into the soil provides food for plants and other organisms. The holes they make improve airflow and drainage. Plant roots grow more easily because the soil is more fertile, softer and better drained.
Holes made by large organisms improve drainage and airflow.

Earthworms burrow through the soil and provide fertile pathways for plant roots to grow along.

Ants are important soil movers. Their underground nests improve airflow, drainage and fertility.

Land crabs move a lot of soil to build their burrows, so they improve soil drainage.
2. Soil organisms shred large pieces of organic matter

Some of the organisms feed on large pieces of organic matter such as dead leaves and roots, dead wood and dried manure. Shredding organisms include beetles, slaters, centipedes, collembola and mites.

Benefits

The large pieces are broken down into smaller pieces that can then be eaten and decomposed by smaller organisms. If the larger pieces were not broken down the land would be covered in dead wood and leaves.
These pieces of wood are being broken down by soil organisms such as termites.

Beetles such as these shred large pieces of organic matter.

Mites help shred organic matter.
3. Soil organisms decompose organic matter

Microscopic organisms such as bacteria and fungi feed on tiny pieces of organic matter and decompose it into:

- food for plants such as nitrogen (N), phosphorus (P) and potassium (K)
- food for microorganisms (carbon)
- humus (smallest units of organic matter that cannot be broken down any further).

Bacteria and fungi are very small, and cannot be seen by eye. The fungi that we can see on or above the soil surface (e.g., mushrooms) are the fruiting bodies of soil fungi.

We see the process of decomposition as rotting and decay.

Benefits

The decomposition process provides fertiliser for plants, such as nitrogen and phosphorus.

Decomposition also produces humus, dark fertile organic matter with high carbon content that holds nutrients and moisture. As a general rule, the darker the soil the more fertile it is.

Microorganisms store nutrients in their bodies, so when they die the nutrients also become available for plant use.
When organic matter rots and decays like this, microorganisms are actively breaking it down.

Humus is dark, fertile organic matter with high carbon content that holds nutrients and moisture.

Composted organic matter is high in humus.

Fungi such as this toadstool indicates there is plenty of microscopic fungi in the soil.
4. Soil organisms help plant roots to access more nutrients in the soil

There are two important soil organisms that help plants get more nutrients from the soil.

1. *Rhizobium* bacteria live in nodules on legume plant roots and fix nitrogen from the air in the nodule. The plant can then use this extra nitrogen and in return give carbon to the bacteria so they can survive. If the nodule is small and white inside, it is not actively fixing nitrogen. The pink/orange colour inside a large nodule indicates that it is actively fixing nitrogen. In the tropics, the black colour inside a large nodule could also indicate that it is actively fixing nitrogen.

2. Mycorrhizal fungi attach to plant roots and extend into the soil to obtain extra nutrients, particularly phosphorus. Mycorrhizal fungi have many plant hosts and occur naturally in most healthy soils.

**Benefits**

Peanuts and soybeans depend on *Rhizobium* for nitrogen, so the bacteria will save farmers some nitrogen fertiliser costs. Sometimes the bacteria occur naturally in the soil, but usually farmers have to inoculate the legume seed with the bacteria before planting. The seed for a legume crop should be inoculated before planting.

Mycorrhizal fungi save on fertiliser costs, particularly phosphorus.
The white mycorrhizal fungi threads attached to the yellow plant roots help the roots obtain more nutrients from the soil.

nodules containing \textit{Rhizobium} bacteria

on Aceh peanut roots

on Aceh soybean roots

Photo courtesy of Paula Flynn, Iowa State University Extension

5. Soil organisms feed on other organisms to maintain balance in the soil

Food for many soil organisms is other organisms.

For example, bacteria feed on fungi, fungi feed on nematodes, nematodes feed on other nematodes, and mites feed on aphids. This is known as the soil foodweb.

The more types of organisms you have in the soil, the stronger is the foodweb, and the healthier is the soil.

There are some organisms that feed on plant roots and cause problems for farmers. These are known as pathogens. Examples include root knot nematodes, *verticillium* (wilt) and *phytophthora* (root rots).

The presence of pathogens indicates that the balance between the living organisms in the soil is disturbed. The less diversity of soil organisms in the soil, the more likely pathogens are to occur.

In a strong soil foodweb with many organisms, the activity of pathogens is suppressed.

**Benefits**

The foodweb keeps organism species and numbers in balance.

A strong foodweb prevents one species dominating and becoming a pest to the farmer, or causing soil diseases.
Soil health depends on biological diversity.

- Organic matter
- Ants
- Mice
- Insects
- Nematodes
- Bacteria and fungi
- Springtails
- Leaf litter
- Reptiles
- Birds
6. Soil organisms improve soil structure

When they feed, soil organisms produce organic ‘glues’ and fungal threads that hold individual soil particles and bits of organic matter together to form soil lump or aggregate.

Soil aggregates are the basis of good soil structure and healthy soil.

It is almost impossible to improve soil structure without the help of soil organisms.

Benefits

Tiny spaces within the aggregates hold air, water and nutrients that plant roots and soil organisms can access.

The large spaces between the aggregates allow excess water to drain away so that plants and soil organisms do not ‘drown’.
Each soil aggregate holds moisture and nutrients for plant roots to use.

Soil aggregates encourage good airflow and allow water to drain freely through the soil.

This soil aggregate is held together by threads of fungi and organic glues produced by microorganisms and earthworms.

This microscope photo shows how threads of fungi bind soil particles together.

Gupta VVSR, CSIRO Entomology
B. What farmers can do to encourage organisms to live in the soil

1. Provide plenty of food
2. Provide water and air
3. Provide suitable habitat
4. Keep soil pH between 5 and 8
5. Use integrated pest management (IPM) to protect beneficial organisms
1. Provide plenty of food

The main food sources for soil organisms that farmers can provide are compost, dead plant material (mulch), green manure crops, animal manures and dead creatures.

Compost provides nutrients so can save some fertiliser costs.

Mulch provides organic matter, holds moisture in the soil, prevents erosion and protects the soil organisms from high temperatures.

Adding compost and mulch to the soil increases the variety of organisms in the soil.

Green manure crops provide organic matter for soil organisms but cultivating them into the soil destroys the organisms' homes.

Manure is a nutrient-rich food source for many soil organisms and plants. It also adds many new organisms to the soil.

When dead creatures are buried in the soil and rot down they provide valuable food sources for soil organisms.

Exudations from living plant roots provide food for many microorganisms in the soil, so it is important to grow as many different plants as possible. They will have a great variety of roots and root exudates, so will encourage more microorganisms.

It is a good idea to change dryland crops each growing season to introduce new plant species, and new food sources for soil organisms.
compost  stubble or mulch  compost

green manure  animal manure  wide variety of plants
2. Provide sufficient water and air

Soil organisms need oxygen and moisture. Soil with good structure has good airflow and stores moisture that organisms can use.

When soil is dry, many microorganisms go into a resting phase and reactivate when rain falls.
Moisture held in soil aggregates

Spaces for airflow and drainage
3. Provide suitable habitat

Soil organisms need somewhere suitable to live.

Some shelter in the layer of organic matter on the soil surface.

Some live in spaces they make themselves, such as burrows and channels.

Some microorganisms live in spaces created by the natural soil structure.

Many microorganisms live very close to plant roots because they feed on root exudates.

If you have bare, compacted soil you will have very little habitat for soil organisms.
Some organisms shelter in the organic matter on the

Many microorganisms live very close to plant roots because they feed on root exudates.

Some live in spaces they make themselves such as burrows and channels.
4. Maintain soil pH between 5 and 8

Soil pH is a measure of soil acidity.
Soil with pH less than 5 is too acidic for most food crops.
Neutral soils have pH of 7.
Alkaline soils have pH of more than 7.
Most soil organisms and plants prefer to live in soils with a relatively neutral PH (around 5-8).

<table>
<thead>
<tr>
<th>Concentration of hydrogen ions compared to distilled water</th>
<th>pH</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>10,000,000</td>
<td>0</td>
<td>Battery acid</td>
</tr>
<tr>
<td>1,000,000</td>
<td>1</td>
<td>Hydrochloric acid</td>
</tr>
<tr>
<td>100,000</td>
<td>2</td>
<td>Lemon juice, vinegar</td>
</tr>
<tr>
<td>10,000</td>
<td>3</td>
<td>Grapefruit, orange juice</td>
</tr>
<tr>
<td>1,000</td>
<td>4</td>
<td>Tomato juice, acid rain</td>
</tr>
<tr>
<td>1000</td>
<td>5</td>
<td>Black coffee</td>
</tr>
<tr>
<td>100</td>
<td>6</td>
<td>Urine, saliva</td>
</tr>
<tr>
<td>10</td>
<td>7</td>
<td>'pure' water</td>
</tr>
<tr>
<td>1</td>
<td>8</td>
<td>Sea water</td>
</tr>
<tr>
<td>1/10</td>
<td>9</td>
<td>baking soda</td>
</tr>
<tr>
<td>1/100</td>
<td>10</td>
<td>Milk of magnesia</td>
</tr>
<tr>
<td>1/1000</td>
<td>11</td>
<td>Ammonia solution</td>
</tr>
<tr>
<td>1/10,000</td>
<td>12</td>
<td>Soapy water</td>
</tr>
<tr>
<td>1/100,000</td>
<td>13</td>
<td>Bleaches, oven cleaner</td>
</tr>
<tr>
<td>1/1,000,000</td>
<td>14</td>
<td>Liquid drain cleaner</td>
</tr>
</tbody>
</table>

Soil organisms prefer pH levels in this range.
5. Use integrated pest management (IPM) to protect beneficial organisms

Pesticides and fungicides harm beneficial organisms that live in the soil for part of their life. Use IPM systems to minimise the use of these products.

Pesticides and fungicides also reduce the total number of organisms and species in the soil, which encourages soil pathogens to dominate the soil.
C. Reasons why soil organisms will not live in your soil

1. Not enough food
2. Soil is compacted
3. Soil is too wet
4. Soil is too dry
5. Soil is saline
6. Soil’s pH is unsuitable
7. Soil is too hot
1. Not enough food

Soil organisms cannot live without food so they do not survive in areas where no plants grow.
2. Soil is compacted

Compaction occurs when soil particles are squashed together by pressure from humans, animal hooves or machinery.

When soils are compacted, there is no air for organisms to breathe, and no spaces for them to live in.

In compacted soils, plants cannot grow easily which means less organic matter for soil organisms to feed on.

However, in rice production compaction is necessary to hold water in the rice bays, so few soil organisms live in rice soils.
In well structured soil
plant roots can grow
freely through the soil.

Plant roots cannot enter
compacted soil so they
cannot access moisture
or nutrients.
3. Soil is too wet

Most soil organisms need oxygen, so cannot live in waterlogged soils.
4. Soil is too dry

Soil organisms must have moisture to survive.
In droughts, some soil organisms become dormant and then become active when it rains.

The smell of rain on dry ground is actually the smell of bacteria spores coming active.
5. Soil is saline

When soil is too salty, crops wilt and die,
so there is no food available for soil organisms.
When salt levels in the soil are 4
deci-Siemens/metre (dS/m) or above,
as shown here, the soil is too saline
for plants to grow.
6. Soil pH is unsuitable

Most organisms cannot live in soils that are too acidic (less than pH 5) or too alkaline (more than pH 8).
Outside pH range of 5-8, most soil organisms will die, so the few remaining species may become plant pathogens.

This soil in this photo is so acidic that most plants cannot grow well.
7. Soil is too hot

Mulch is used to conserve moisture and prevent weed growth. However, plastic mulch reduces the food supply for organisms and heats the soil so that it is too hot for organisms to live in.
D. Issues that affect soil organisms in Aceh

1. Lowland rice growing
2. Poor drainage in coastal soils
3. Fast decomposition of organic matter
4. Use of agricultural chemicals
1. Lowland rice growing

Rice field soils are ploughed and compacted so that they will hold water. This means very few soil organisms can survive these conditions. One organism that can survive is the nitrogen-fixing algae found in the rice paddy water.

If a dryland crop is planted in the rice paddy, you need to add a lot of organic matter (e.g., mulch, manure, compost) to encourage soil organisms and restore soil health.
2. Poor drainage in coastal soils

Poor drainage in coastal soils means there is not enough oxygen available for soil organisms.

To improve drainage in waterlogged soils, build crop beds higher than the water level so that plant roots are not in water and soil organisms can survive.
3. Rapid decomposition of organic matter

Aceh’s hot and humid climate provides ideal conditions for soil organisms to multiply. This means they quickly eat any organic matter available, and when there is no food left will die out.

To keep organisms in the soil, Aceh farmers need to provide large quantities of organic matter frequently.

Sources of organic matter available in Aceh include mulch, cow manure, chicken manure, compost, and fish emulsion.
4. Use of agricultural chemicals

Excessive use of agricultural chemicals can kill beneficial soil organisms.

In Aceh beneficial insects include beetles that eat leaf chewing grubs in soybean crops.
Farmers in Aceh need to inspect their crops to see what is living there before they spray.
If there are a lot of beneficial insects eating the crop pests, they may not need to spray, which will save money and benefit soil organisms.
The health of crops depends on the health of organisms in the soil, and the health of organisms in the soil depends on the farmer.
Acknowledgements

WORKSHOP PARTICIPANTS IN DESA SEUKE, PIDIE
T. Zulkifli M. Gade Zulkifli Ernawati Tarmizi Ellyzar Yulinda Muhammad Hamdiah Tarmizi Ramli Rusydi Jalaluddin Mukhlis Maimuntazar Samidan M. Amni Rosita Muhammad Jamil Detti Azwani Nazaruddin Ismail A. Wahid Rusdi Tahir Efendi Abu Bakar Iskandar Sabi Efendi K.

WORKSHOP PARTICIPANTS IN DESA PINEM, ACEH BARAT

Organisers of the successful workshops in Aceh
Ir Basri Abubakar Msi Ir Chairunas Ms Irhas Ir M Nasir Ali
and team members from Balai Pengkajian Technologi Pertanian (BPTP) NAD

Dr. Iwan Juliardi (late) and Dr. Anischan Gani from ICRR, Sukamandi

Dr. Fachmudin Agus, Dr. Ai Dariah, and team members from ISRI, Bogor