Chapter 7
Monitoring impacts of land management: a problem-solving perspective

Land-management systems have an impact on soil environment. Soil physical, chemical and biological properties are modified considerably by agricultural practices. They may affect soil organisms either positively or negatively, so modifying the size and composition of soil biological communities, with important consequences on soil fertility and plant productivity (Table 5).

TABLE 5
Effects of different management practices on soil organisms and soil function

Management practice	Effect on soil organisms and function
Tillage	More rapid decomposition of organic matter; higher ratio of bacteria/fungi; lower populations of macrofauna and mesofauna; short-term increase in nutrient availability but increase in long-term losses; better root growth in tilled layer; higher erosion risks.
No-tillage	Higher populations of macrofauna, mesofauna and microfauna; greater ratio of fungi/bacteria; organic matter accumulation on soil surface; nutrient conservation; lower runoff and erosion; increase in presence and incidence of pests and diseases.
Organic matter input	Changes in decomposition rates and organism populations (some increase, others decrease, depending on the type of material); increased nutrient availability, storage and exchanges; improved soil physical structure and water relations; reduction in acidity and aluminium toxicity; greater microbial and fauna activity, especially detritivores.
Fertilization	Usually, reduction in mycorrhization and N_2 fixation (with P and N, respectively); mineralization-immobilization balance changes; increased plant production and organic matter inputs; increases in populations of some organisms through greater food supply.
Pesticides	Reduced incidence of diseases and pest, parasites and pathogenic organisms, but negative effects on non-target biota such as beneficial insects and earthworms; improved plant production but often creation of dependence; destabilization of nutrient cycles; loss of soil structure; long-term increased resistance of target biota.
Crop rotations	The “rotation effect”; improved pest and disease management; more efficient soil nutrient utilization; greater diversity aboveground and belowground; higher populations, biomass and activity of most organisms (especially with legumes); improved soil aggregation and infiltration; reduced bulk density; higher organic matter.
Inoculation of selected soil biota (e.g. rhizobia, mycorrhizae, earthworms,rhizo-bacteria, antagonists, biocontrol agents)	Increased N fixation, nutrient availability in soil, water uptake and efficiency of nutrient acquisition by plants; higher yields; increased heavy metal tolerance; better resistance to plant diseases, pests and parasites; increased soil porosity, aeration, aggregate stability, water infiltration and holding capacity; faster decomposition rates and nutrient cycling.

Source: expanded from Swift (1997).

Clearing forests or grasslands for cultivation modifies the soil environment drastically and, hence, also modifies the numbers and kinds of soil organisms. The quantity and quality of plant residues and the number of plant species are, in general, greatly reduced, as a result the range of habitats and foods for soil organisms is reduced significantly. The use of large quantities of agrochemicals (pesticides, herbicides and inorganic fertilizers) and tillage practices has a negative influence on soil communities by reducing their numbers and hence the beneficial ecological functions in which they participate.

The beneficial effects of soil organisms on agricultural productivity that may be affected include:

- organic matter decomposition and soil aggregation;
- breakdown of toxic compounds, both metabolic by-products of organisms and agrochemicals;
- inorganic transformations that make available nitrates, sulphates and phosphates as well as essential elements such as iron (Fe) and manganese (Mn);
- N-fixation into forms usable by higher plants.

Decomposition is the central process in soil. The breakdown of organic residues by soil microflora to release plant nutrients is often accelerated in the presence of soil fauna (Swift *et al*., 1979; Seastedt, 1984; Tian *et al*., 1992). The breakdown of plant residues by soil fauna increases the exposure of substrates to the microflora, leading to enhanced nutrient release (Scheu and Wolters, 1991).

In the humid tropics (e.g. Nigeria), the rate of breakdown of plant residues where earthworms and millipedes are present may be twice as high as where they are not present (Tian *et al*., 1997).

Farmers need to create favourable conditions for soil life. They should manage organic matter so as to create a fertile soil in which healthy plants can grow. In tropical agriculture, where poor farmers generally suffer from decreasing soil fertility and declining soil water dynamics, the restoration of SOM is essential for the stabilization of production. Declining soil water dynamics is partly a result of drought conditions but also significantly affected by loss of vegetation cover, soil crusting and compaction and loss of soil organic matter. These result in reduced surface infiltration, water retention and permeability through the soil as well as increased runoff and hence erosion.

However, this situation cannot be achieved by merely incorporating organic matter into the soil as the degradation process under tropical conditions is too fast to allow any medium- or long-term improvement in soil properties. In addition, the incorporation into soil of organic matter implies tilling the soil, which accelerates its breakdown and destroys soil structure and organisms.

The primary need is to feed soil organisms and to regulate their living conditions, while protecting them from harmful chemical and mechanical impacts. For example, shallow tillage, ridge-tillage, or no-tillage and surface management of crop residues has often led to increases in earthworm activity compared with areas where deep tillage is practised. Earthworms are a resource that may be used in agriculture because their effects on nutrient dynamics and the physical structure of soil may significantly enhance plant growth and conserve soil quality (Jiménez and Thomas, 2001). Management options that stimulate the activities of these organisms could promote sustainable production in tropical agro-ecosystems (Swift, 1987; Myers *et al*., 1994).

For example, the success of earthworm-management techniques may depend on: the choice of suitable species; the provision of adequate organic supplies to feed the worms; and the maintenance of a minimum diversity in all invertebrate communities. Therefore, all these biological resources need to be managed at the same time (Senapati *et al*., 1999).

In the humid tropics, "in-soil" technologies that incorporate organic residues into the soil to stimulate the activities of local or inoculated populations of soil-dwelling earthworms should be preferred in most cases to "off-soil" techniques (vermicomposting) that simply use earthworms to prepare compost. The vermicomposting of residues allows the rapid transformation of fresh residues into compost that can be used readily in the field. However, a large amount of C is lost that might have been used to sustain mechanical activities of earthworms and other invertebrates in the soil. Endogeic earthworms participate in the humification of organic matter, but they also contribute to: the macroaggregation of soil particles; the maintenance of macroporosity; and the intimate mixing of organic compounds, with effects on the long-term sustainability of soil fertility (Blanchart *et al*., 1997). Vermicomposting should only be recommended when the quality, the amount or the location of organic residues makes them unsuitable for local use in agriculture. "In-soil" technologies are based on the use of endogeic and anecic earthworms that influence soil physical properties significantly. These technologies manipulate earthworm communities either directly, through the massive inoculation of suitable populations, or indirectly, by promoting suitable conditions for the activity of the already existing population through the manipulation of plant communities and/or organic inputs.

The loss of SOM and nutrient deficiency is one of the most important problems facing farmers. SOM is of key importance to optimizing crop production, minimizing environmental impacts and, thus, improving soil quality and the long-term sustainability of agriculture. SOM benefits crops by providing nutrients, especially N, as it is decomposed by microorganisms. Furthermore, it: (i) binds soil particles together so that they prevent erosion; (ii) improves soil structure and tilth, which allows water, air and nutrients to move readily to living organisms; (iii) is a strong absorber of pesticides, organic wastes and heavy metals; and (iv) is a part of the cation exchange complex, which holds many nutrients and resists losses to leaching.

In a natural grassland or forest ecosystem, SOM accumulates with soil development and eventually reaches an equilibrium, which is determined mainly by the environment, natural vegetation and soil organisms. A decrease in SOM leads to a decline in soil aggregate stability (Castro Filho *et al*., 1998) and in crop yield (Burle *et al*., 1997). Where soil is tilled and cropped, massive changes occur within the soil system.

Tillage mixes oxygen into the soil and breaks up its structure, giving microbes all they need in order to burn up organic matter and release CO_2 into the atmosphere more quickly than when this process is realized naturally by soil organisms. In the natural state, much of the SOM is protected. The soil system can be thought of as a structure with millions of tiny pores of all sizes and shapes. Much of the SOM is trapped in areas inaccessible to microbes. Other organic particles are clumped (aggregated) together, so allowing microbes access to the outside while the centre remains protected. Soil organisms such as earthworms mix SOM and mineral particles, thereby facilitating its access by microorganisms. Tillage speeds up this process; stirring, churning and mixing everything together. Microbes suddenly find a feast of nutrient rich material and proceed to multiply, liberating excess nutrients that, if not taken up by the crop, vulnerable to be leached out of the soil with rain or irrigation water.

The rate and degree of organic matter depletion is influenced by: (i) type of crop residues; (ii) tillage practices; and (iii) type and severity of wind and water erosion.

In conventional agro-ecosystems, crop residues are removed or burned after harvesting. Unless other organic materials are added to the soil, this will lower the amount of SOM, and so inorganic nutrient inputs are needed to sustain plant growth. The loss of SOM has a negative effect on soil macroinvertebrates, whose abundance decreases as a consequence of the reduced amount of food available. In addition, conventional systems are characterized by repetitive tillage, which physically disturbs the soil and reduces greatly the abundance of soil macrofauna. Most SOM is contained in the surface horizons of soils. Soils become more sensitive to erosion under such management practices, and the physical removal of topsoil by wind and water erosion can result in a further significant loss of organic matter.

Organic matter losses can be minimized through the application of conservation farming practices, which include:

- using permanent crop covers to prevent erosion and add organic matter;
- employing crop rotations that include forages and legumes;
- adding manures and organic wastes to supplement crop residues;
- realizing mulching on the soil surface;
- using an adequate and balanced fertilizer programme that creates healthy crops and good residues;
- using no-tillage where possible or minimum tillage;
- In no-tillage, seed is drilled directly into the stubble or the surface residues which have been flattened with a knife roller or killed with a herbicide without first ploughing the soil.

The use of no-tillage in different kinds of crops in the Parana region (southern Brazil) has improved soil environmental conditions for plants and soil animals compared with soils under conventional tillage management systems. Results include: reduced erosion; enhanced nutrient-use and water-use efficiency by crops; and improved crop yields and profitability, especially after a transition period of a few years. No-tillage practices have also increased soil macrofauna diversity and accelerated population recovery after the cessation of conventional tillage practices. Soil organisms that have benefited especially from no-tillage are: natural predators (important for the biological control of pests); bioturbators (important for improving soil physical structure); and decomposers (important for recycling plant residues). Finally, the lack of soil disturbance at no-tillage sites has led to: increased SOM in the top-most soil layers; increased protection of the soil surface with plant residues; and increased populations of beneficial soil invertebrates (FAO report, 2000).

In contrast to ploughed systems, no-tillage management leads to accumulation of plant residues on the soil surface. This decreases the rate of decay of crop material and, therefore, helps to maintain good SOM levels. The adoption of soil conservation practices that reduce soil erosion will assist in reducing losses and maintaining SOM.

Increasing the amount of crop residue will also assist in maintaining and/ or increasing SOM levels. This can be accomplished by selecting crops that produce more residue, by adequate fertilization and by rotations of cereals with legumes and forage crops, especially those with deep extensive rooting, as well as minimising the removal or burning of crop residues. In sandy soils or soils low in organic matter, the addition of manure and the inclusion of legumes in the rotation, or as a green manure crop, will be needed to enhance SOM and minimise fertiliser losses (if used) through leaching.

Conventional tillage practices, based on the use of hand hoes, ploughs – animal drawn and powered – and harrows are likely to destroy soil structure and make the soil vulnerable to compaction and erosion. Wheel traffic or pressure (weight per unit area) exerted on the soil surface by large animals, vehicles and people can cause soil compaction. Compaction occurs where moist or wet soil aggregates are pressed together and the pore space between them is reduced. Compaction changes soil structure, reduces the size and continuity of pores, and increases soil density (bulk density). Compaction reduces the capacity of the soil to hold water, the rate of water movement through the soil, and the storage capacity of the soil. Compaction and crusting of the soil surface also limits water infiltration resulting in increased runoff and vulnerability to erosion and hence further loss of potential productivity. When the amount of water that enters the soil is reduced, less water is available for plant growth and percolation to deep root zones.

Soil compaction can also be caused indirectly by a decrease in soil organisms and hence loss of biological tillage.

Deep tillage is harmful to soil organisms. It can kill them outright, disrupt their burrows, lower soil moisture, and reduce the amount and availability of their food. Other inappropriate land-management practices, such as the use of certain pesticides and some inorganic fertilizers, can also be harmful to soil life. All these practices result in declining soil life and SOM, which are important for oxygen, water and nutrient cycles, including moisture retention, water infiltration and plant nutrition. In general, soil tillage reduces the abundance of soil organisms. Termites, earthworms, beetles and spiders are among the main groups of soil macrofauna usually much reduced by tillage practices (Wardle, 1995). As they are reduced, their functions in soils (burrowing, decomposition and cycling of nutrients, soil aggregation and predation) are altered, leading to soil degradation and increases in pests and plant diseases.

Compaction reduces the capacity of the soil to hold water, the rate of water movement through the soil, and the storage capacity of the soil. Compaction and crusting of the soil surface also limits water infiltration resulting in increased runoff and vulnerability to erosion and hence further loss of potential productivity. When the amount of water that enters the soil is reduced, less water is available for plant growth and percolation to deep root zones.

The alteration of soil macrofauna abundance and diversity as consequence of soil-management practices may lead to serious problems of soil compaction. The functions previously performed by depleted organisms are no longer performed and the activity of surviving organisms may become excessive and produce a negative effect on soil. In the Brazilian Amazon (Manaus) the transformation of the forest zones into pastures, the use of agricultural machinery and trampling by cattle has led to severe soil compaction, particularly in the surface layer (5–10 cm). However, the most important consequence was that the native soil macrofauna communities were radically altered, most of the native taxa disappearing. The activity of the compacting earthworm species *Pontoscolex corethrurus* produces more than 100 tonnes/ha of castings. The excessive accumulation of these compacted structures is wholly prevented by small invertebrates that feed on them and break them down into smaller structures. However, where these organisms are not present because of soil compaction by cattle or machinery, this function is not performed and the accumulation of compacted casts affects plant growth negatively (Chauvel *et al*., 1999).

Where soil density increases significantly, it limits plant growth by physically restricting root growth. Severe compaction can limit roots to the upper soil layers, effectively cutting off access to the water and nutrients stored deeper in the soil. Anaerobic conditions (lack of oxygen) can develop in and above the compacted layer during wet periods, further limiting root growth.

Compaction alters soil moisture and temperature, which control microbial activity in the soil and the release of nutrients to plants. Anaerobic conditions increase the loss of soil N through microbial activity. Compaction also changes the depth and pattern of root growth. These changes affect the contribution of root biomass to SOM and nutrients. By reducing the number of large pores, compaction can restrict the habitat for the larger soil organisms that play a role in nutrient cycling and can thus reduce their numbers.

Biological activity may be used to reduce soil compaction. In Burkina Faso, organic mulch (cow manure or straw) was applied to soil surfaces in a three-year study in order to trigger termite activity (Mando, 1997). The termites restored crusted soils through their burrowing and decomposing activities, properly managed by careful additions of organic matter. The increase in soil porosity and the improvement in water infiltration and retention capabilities of the soil encouraged root penetration and hence crop productivity. Termites can become a major crop pest in drylands when there is inadequate alternative dead and dried up organic matter – their preferred food source. Best practices and deterrents need to be researched and adapted with farmers for specific farming systems. For example, making use of termite predators, such as ants and birds, through diversified farming systems, reducing plant water stress and vulnerability to termite attack, and use of plants with repellent properties.

Soils with a well-developed structure and high aggregate stability are more resistant to compression than other soils. Near-surface roots, plant litter, and aboveground plant parts reduce the susceptibility to compaction by helping to cushion impacts. Vegetation also adds SOM, which strengthens the soil, making it more resistant to compaction. Conventional tillage, especially in tropical latitudes, causes rapid oxidation and mineralization of organic matter and, as a result, declining SOM levels.

Conservation tillage is linked with increased earthworm activity (Mele and Carter, 1999); mulched stubble in particular favouring large increases in earthworm numbers. The retention of maximum levels of crop residues on the soil surface and a lack of soil disturbance create a more favourable habitat for soil animals. Earthworm channels and termite galleries increase the volume of soil pores, which should increase soil aeration and water entry into the soil (Ehlers, 1975; Holt *et al.*, 1996). The number of large soil pores under no-tillage practices can be up to sevenfold greater than under conventional tillage systems.

Another practice to improve a compacted soil is the growing of plants with large taproots that are more effective at penetrating and loosening deep compacted layers, and the use of shallow, fibrous root system to break up compacted layers near the surface. Roots also reduce compaction by providing food that increases the activity of soil organisms.

Conventional tillage methods are a major cause of severe soil loss and desertification through soil compaction and accelerated erosion by wind and water. Worldwide, it is responsible for about 40 percent of land degradation. Agricultural lands could be protected or saved from degradation and erosion by applying an environmentally friendly tillage approach and the use of cover crops and mulching practices.

The intensity of tillage is a recognized factor affecting the amount of runoff and soil erosion that occur in croplands. In turn, the amount of runoff and soil loss directly affects soluble and absorbed chemical transport, particularly plant nutrients from fertilizer application. Soils with no-tillage management practices present a much lower sediment loss than soils under conventional practices. No-tillage keeps crop residues on the soil surface, which is highly effective in controlling the loss of sediment from water-runoff events. The loss of soil nutrients such as soluble N and P is reduced by up to 50 percent where no-tillage is adopted.

Conventional tillage, especially in tropical latitudes, causes rapid oxidation and mineralization of organic matter and, as a result, declining SOM levels. Thus, no tillage practices are highly preferable as they leave a protective blanket of leaves, stems and stalks from the previous crop on the surface, to protect the soil from erosion, minimise compaction and maintain soil structure, enhance infiltration and provide organic matter for soil biological activity. These also lead to enhanced fertiliser efficiency.

There are several ways of modifying tillage systems to improve soil resistance to erosion and enhance soil macrofauna populations:

- leave a rough surface or adequate residue cover for erosion control;
- bury crop residues for pest control, depending on the system;
- leave as mulch cover when possible;
- do as little physical disruption (tillage) as possible;
- use crop rotations with specialized cover crops – essential for breaking the cycles of weeds and pests and for compensating for higher-value crops with inadequate quantity and quality of residues, such as edible beans and soybeans, with high C:N ratios in their straw.

The adoption of conservation tillage is sometimes restricted by concerns about potential increases in certain pests, particularly plant pathogens and insect pests. The complex interactions within a more diverse soil community in no-tillage may provide protection against the pest organisms, but the time required for this shift in communities may be too long for farmers' economic requirements. The use of synthetic chemical pesticides, particularly herbicides, may be unavoidable in the early years, but they have to be used with care in order to reduce the negative impacts on soil life. To the extent that a new balance between the organisms of the farm-ecosystem, pests and beneficial organisms, crops and weeds, becomes established and the farmer learns to manage the cropping system, the use of synthetic pesticides and mineral fertilizer tends to decline to a level below the original "conventional" farming level.

Where soil insects become a pest, they contribute to a poor yield. The damage caused by pests can be responsible for 40–50 percent of crop loss. Groundnut plants are particularly susceptible to attacks by soil insects because the pods develop underground. Groundnut culture is an important crop and component of the diets of many smallholders in sub-Sahelian Africa. They have access only to 1–2 ha, from which they derive the food to support their family and sometimes all their income.

Soil organisms like white grubs, e.g. *Diabrotica* larvae, some species of termites, millipedes, wireworms (Elateridae), false wireworms (Tenebrionidae) and ants can became serious groundnut pests in Africa, Asia, and Central and South America. All these organisms are podborers and attack roots, causing important crop loss.

There are four basic approaches for managing soil insects in groundnut crops:

- apply insecticides, alone or in various combinations;

- manipulate natural control processes;
- rely on host plant resistance;
- employ management practices that prevent the insects from multiplying unduly

The application of insecticides is not recommended because they are usually not sufficiently effective and they are expensive. Aside from the well-known hazards that these chemicals present to the environment and humans, they can be accumulated by plants. These chemicals are not pest specific and kill other beneficial organisms present in soils. This can led to the proliferation of other organisms that become more harmful. For example, in a Malawi field, there was a proliferation of termites following an insecticide application because of the disappearance of their natural enemies, the ants.

It is most important that the natural control processes should not be disturbed. Thus, the unavailability of insecticides in many African countries is not necessarily a bad thing. The abundance of natural enemies indicates that there is little reason for considering the release of exotic or any other natural enemies. However, any management procedure that encourages the proliferation of suitable predators and parasites should be considered the best solution.

In Cuba, the banana weevil *Cosmopolites sordidus* is an important pest that may be responsible for up to 40 percent of crop loss. Some ant species, beetles and earwigs are natural predators of this beetle and they may reduce banana weevil populations significantly. The creation in banana plantations of environmental conditions suitable for the development of these predators appears to be the best way to realize a biological control. Integrated pest management is imperative as it is an effective and cost-efficient system (Gold and Messiaen, 2000; FAO report, 2000).

In Nigeria, a way of controlling termite invasions is to cultivate plants that have repellent or antibiotic properties, or at least not to remove them from the fields. The plants include: basil, termite grass *Vetiveria nigritana*, *Digitaria sp.*, lemon grass *Cymbopogon shoenanthus*, and elephant grass *Pennisetum purpureum*. Some farmers also introduce soldier ants into termite mounds.

Spacing can also have a significant effect on the damage caused by pests (Jayaraj *et al*., 1986). A study in India showed that in plots with 15-cm spacing between cotton plants in rows spaced 75 cm apart, the average percentage of attacks by the ash weevil grubs was 17 compared with 22 percent in 20-cm spacing and 31 percent in 30-cm row spacing.

Crop rotation and intercropping using plants that are not hosts for a certain pest are very important to preventing the survival and the continuous reproduction of the pest throughout the year.

The best solution to problems caused by pests could be a whole-farm ecological approach to pest management that considers beneficial organisms as mini-livestock that can be managed (Dufour, 2000). These organisms could develop more readily and be more effective biocontrols when provided with a habitat with adequate and easily available resources. This way to increase the habitat for beneficial organisms should be understood and practised within the context of overall farm management goals.

Some key questions that could help in the implementation of a such system are:

- ➢ concerning pest and beneficial organisms:
  - What is the most important pest (in economic terms) that requires management?
  - What are the most important predators and parasites of the pest?
  - What are the primary food sources, habitat and other ecological requirements of both the pest and of beneficial organisms? (Where does the pest infest the field from, how is it attracted to the crop, and how does it develop in the crop? Where do the beneficial organisms come from, how are they attracted to the crop and how do they develop in the crop?)
- ➢ concerning timing:
  - When do pest populations generally first appear and when do these populations become economically damaging?
  - When do the most important predators and parasites of the pest appear?
  - When do food sources (dead organic matter, nectar, pollen, alternate hosts and prey) for beneficials first appear? How long do they last?
  - What native annuals and perennials can provide habitat?

Thus, the identification of strategies to improve field conditions for pest management should consider: reduction of pest habitat (i.e. reduce/alter locations from which pest invades or reduce/alter overwintering pest sites in temperate regions); augmentation of beneficial habitats (insectary establishment; considering both perennial and permanent plantings such as hedgerows and annual options), and trap crops planted specifically to be more attractive to the pest that is the crop to be harvested. Table 6 provides a description of planting systems that can be used in this approach.

The idea of undisturbed beneficial habitat distributed at intervals in or around crop fields is a good solution for these purposes. Depending on the plant species, these "perennial islands" provide food resources for beneficial organisms as well as refuge (or over-wintering sites in temperate regions) from which crops can be colonized.

TABLE 6
Practices for an ecological approach to pest management

Practice	Description
Companion planting	A mix of species of plants within a row or bed – this could be difficult to manage for farmers owing to varying cultural needs such as planting time, irrigation needs and harvesting.
Strip planting, strip cropping	The practice of growing two or more crops across a field wide enough for independent cultivation (e.g. alternating six-row blocks of soybeans and corn or alternating strips of alfalfa with cotton) could be easily adapted to vegetable production systems. Like intercropping, strip cropping increases the diversity of a cropping area, which in turns may help "disguise" the crops from pests. Another advantage is that one of the crops may act as a reservoir and/or food source for beneficial organisms.
Multiple cropping	The production of more of one crop in the same land in one year. Depending on the type of cropping sequence used, multiple cropping can be useful as a weed control measure, particularly where the second crop is interplanted into the first.
Interplanting	The seeding or planting of a crop into a growing stand, such as overseeding a cover crop into a grain stand.
Intercropping	The practice of growing two or more crops in the same, alternate or paired rows in the same area. This technique is particularly appropriate in vegetable production. The advantage of intercropping is that the increased diversity helps to "disguise" crops from insect pests and, where done well, may allow for more efficient utilization of limited soil and water resources.
Cover crops	Cover crops and green manures can be integrated into both perennial and annual cropping systems. Cover crops, often a legume or grass species, prevent soil erosion and suppress weeds. A cover crop can also be used as a green manure.
Green manures	Generally incorporated into the soil to provide N and organic matter for subsequent crops. When incorporated, some cover crops in the Brassica family (e.g. rapeseed, broccoli and radish) have the ability to suppress nematode pests. Left in the field as residues, some grasses will provide more than 90% weed suppression.
Windbreaks, shelterbelts and hedgerows	These are linear barriers of trees, shrubs, perennial forbs and grasses that are planted along field edges or other unused areas. Where done correctly, they reduce windspeed and, as a result, modify the microclimate in the protected area. Aside from providing a microclimate favourable to beneficial organisms, shelterbelts also protect against wind erosion of soil, decrease the dessicating effect of wind on crops, and provide wildlife habitat.
Permanent border	A strip of permanent vegetation bordering a field. A border such as this can be modified to attract beneficial insects through the cropping season if the proper plants are used and sufficient water is made available.