Systems Thinking

by Frank van Steensel

Introduction

During my involvement in the Organic industry in New Zealand I have noticed a certain negativity towards science in the organic movement. I have also noticed that better acceptance of organic and biodynamic farming in other western countries goes hand in hand with a wider acceptance of science within the western organic movement. This has forced the 'conventional' scientist to become more involved. Today, organic agriculture is creating challenges for researchers who have grown aware of the limitations of some conventional approaches in modern science. Slowly but surely their work is gaining more respect in particular areas of science. IFOAM's good reputation is based on its ecological approach. There are researchers exploring these new areas and integrating them into the wider concept of a holistic science. In the previous issue of *Harvests,* I considered the topic of ecological succession. This article concerns systems thinking.

Systems thinking

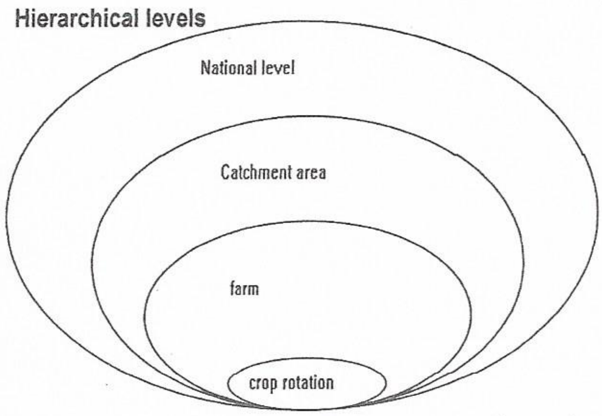
Systems thinking has emerged this century as a complementary approach to analytical thinking in natural science. It involves a holistic rather than a reductionist approach. Its origin lies in organismic biology. Early this century the organismic biologist began to doubt whether reductionism was the best approach to the question, "*What is a living organism?*" To explore this question better they developed what has been termed 'systems thinking'.

The core of systems thinking is that we select an *entity* - (in biodynamic agriculture, we would use the term '*organism*') which can survive in a changing environment and shows:
- a hierarchical structure
-emergent properties - that is, properties that characterise the whole but not the parts. These are hard to detect and measure with analytical tools
- cybernetic control—that is communication and feedback loops that steer towards a (defined) goal.

These *entities* can be as large as complex ecosystems such as a rainforest, or individual plants, animals or micro-organisms. Then we can determine that there is a hierarchy of entities within entities, or systems within systems. Agriculture consists of a hierarchy of eco-systems.

Systems researchers say that the behaviour of higher systems in such a hierarchy is not readily discovered simply from a study of the properties of lower systems, and vice versa. The well being of each level or system depends on a successful functioning of the levels below (which are called the system's *components*) and the level above (the system's *environment*). Though the wording is different the concept is basically the same as that put forward by Rudolf Steiner (1924). He saw the farm as a living system within a hierarchy of living systems. Although modern systems theory doesn't yet encompass the range of entities explicit in Steiner's view, it can provide us with a framework to work with. With this framework we can make a strong case for organic and biodynamic agriculture.

How can we find indicators to judge the well-being of systems? Certain systems biologists developed indicators for agricultural ecosystems. When we use these indicators to assess a properly managed organic or biodynamic farm we can draw certain useful conclusions. Here we will use established research data from a properly designed biodynamic farming system in Germany. Since, next to soil care, biological diversity is one of the basic elements of biodynamic farming, the first level will be the **crop rotation**, the second level will be the **farm**, the third level will be the **catchment area** and the last the **national level.**



Organic **crop rotation** is part of a **farm system**, so it can also be seen as a system of human activity. This means that it is *purposeful*. It not only responds to outside stimuli to achieve some goal, but also, through human activity, the system is redesigned to achieve some new goal. Conway (1985, 1987) and Rambo (1985) defined a list of emergent properties that cover the biological and social components of agroecosystems. These can be applied at the level of organic crop rotations, because it is a lower step in the hierarchical scheme than the agroecosystem – which in this case is the farm.

Agriculture contains a hierarchy of systems from the individual plant, animal or microorganism through to the global food system. As previously mentioned the well-being of each level depends on the successful functioning of the levels below, the systems components, and the level above, the systems environment. To estimate the effect of an organic crop rotation, (a system *component*) in the hierarchy, it will probably be sufficient to consider four levels. Crop rotation will influence higher and lower levels than these, but from these four we will be able to see the significance of the systems approach.

In a **crop rotation**, biological processes dominate the cropping units. Management works down into this level from the level above. The level of crop rotation will also include the population dynamics of plants, animals and microbes that are the focus of an organic crop rotation and the soil, air and water resources upon which these populations depend. One level higher in the hierarchy we find the first social unit, **the farm**. The farmer introduces his goals through management strategies. He works in a physical and socio-economic environment. The third level in this concept is **the catchment** and finally at a **national level** the well being of agriculture is vital for the maintenance of the whole hierarchy.

Organic crop rotation

The purpose of organic crop rotation is to transform crop residues and organic wastes such as manure and compost into an optimum crop production system. Crop rotation is an important part of organic farming because it largely determines whether or what other materials might be required from outside the farm (for example: agri-(bio)chemicals such as soluble fertilisers and pesticides). The purpose of organic farming, as we know, is to limit the use of agri-(bio)chemicals through cycling of living matter. Crop rotation has an important place in reducing agri-(bio)chemicals on the farm and catchment levels. This is possible because of the emergent properties of a well-designed cropping pattern.

Optimal ecological crop rotation can be realised by:
- creating a balance between crops that fix nitrogen or contribute nitrogen and crops that utilise nitrogen
- creating a balance between crops with a closed canopy which restore structure and suppress weeds and crops that impoverish structure and do not suppress weed growth
- reducing the cropping frequencies of crops so that soil borne pests and diseases are manageable

creating a cropping pattern that prevents negative influences and uses positive influences (N-supply, structure, weeds, pests and diseases. Animal manure may only serve as fertiliser in limited amounts because high amounts may cause a dangerous rise in the P and K levels.

On the basis of these directions we need to find a balance between the amount of legume crops and other crops in the rotation. Pests and diseases need special attention because different legumes grown together or with other crops have similar susceptibilities towards the same pests and diseases.

Nitrogen supply

In most cases the ideal situation and the practical situation are not the same. This is also true on many biological/organic farms. The ideal situation would be reached when all the nitrogen on the farm could come from biological N-fixation since soluble fertilisers are not promoted in biological farming.

The design of the farm should thus start with nitrogen balance. As P and K are easier to balance, they fit better than nitrogen in total recycling management. P and K do not volatilise and leaching is generally very limited. They can easily be supplied by using organic wastes and rock phosphate. Not all legumes are capable of fixing large amounts of nitrogen. There are important differences between species and locations. The amount of nitrogen fixed can vary between 0 and 500-600 kilograms per hectare. It is important that the legume chosen is adapted for the location and the time. The Nitrogen balance might look as shown in Table 1.

Table I. Input	Output
N-fixation by legumes	Produce sold
Farm foodstuff and hay or silage	N-losses from animal wastes (20-90%)
N-fixation by free-living bacteria	Denitrification and leaching
N– supply through rain and dust	

A crop rotation with a proper nitrogen balance based on legumes could look like Table 2 (adapted from Kahnt, 1986)
(* *Units = kilogram nitrogen/hectare/year*)

Table 2	N– imput	N-losses
1.Grasses, clover	+300	-170 (milk, meat and losses from manure)
2. Grasses, clover	+400	-170
3. Oats		-110
4. Wheat		-120
5. Beans, peas, barley and clover undersown	+200	-100 (milk, meat and losses from manure)
6. Potato		-100
7. Wheat		-120
8. Beans	+350	-225 (½ sold, ½ fodder)
9. Winter barley and clover (undersown)	+50	-50 (fodder)
TOTALS	**+1400**	**-1240 ***

This crop rotation scheme has a two-year pasture that suppresses perennial weeds, increases the soil organic matter content and improves soil structure. The cropping pattern prevents a build up of soil borne pest and diseases. It is a good example of an organic crop rotation. Adaptations can be made depending on the farm, farm location, and socio-economic considerations.

Pest and diseases

Crop rotation is a preventive measurement for pests and diseases. It creates a balanced use of nutrients from the soil and / or exudation of plant roots. This creates the right environment for a balanced plant development that is more resistant to pests and diseases. Crop rotations from one to five years prevent the occurrence of many diseases and pests such as nematodes and soil fungi. Crop rotation does not prevent outbreaks of pests like beetle grubs and slugs and diseases where there are many host plants. Crop rotation does not give protection against organisms that do not spend a part of their life cycle in the soil, for example, aphids, caterpillars, botrytes, mildew, and rust. Many pests spread because the adults can fly. Crop rotation cannot prevent that. Even if crop rotation does not prevent these pests and diseases it is still useful for the general health of the crop.

Conway and Valentyne, in the early 'nineties, recognised sustainability as an *emergent property* of an agroecosystem. If we adapt the indicators of sustainability suggested by system thinkers we can theoretically, come to a reasonable assessment of the sustainability of this organic crop rotation. Table 3 assesses the farm, using suggested indicators of sustainable agriculture for each level in the agricultural hierarchy (adapted from Valentyne).

Key
+++ = highly acceptable
++ = very acceptable
+ = acceptable
= doubtful
- = unacceptable

Cropping unit level

Soil organic matter ++
The organic matter content stabilises because there is no direct demand from the crops on the humus content of the soil. Mineralisation of fresh organic matter prevents the breakdown of humus. This crop rotation design takes into account a mineral balance that prevents a decrease in organic matter because all mineral requirements for the crops are met with legumes, crop residues, animal manure and compost.

Soil biological activity ++
Soil biological activity will also stabilise because soil organic matter does not decrease. Soil organic matter will supply food for soil life and it creates an optimum environment for most of the useful soil organisms. Eliminating the use of agri-(bio) chemicals will also contribute towards more harmonious biological activity in the soil. Mineral balances and ecological balances are undisturbed and a more harmonious, stable environment is created for soil life.

Soil toxin levels ++
Soil toxin levels will be low (although this depends on the history of the farm). Agri-chemicals (certainly persisting agri-chemicals) are not promoted. Increasing nutrient levels are not likely under conditions that enable nutrient recycling. Off-farm inputs need to be checked.

Table 3 CROP ROTATION	FARM	CATCHMENT	NATION
Soil organic matter ++	Biological and economic diversity ++	Water/air contamination +	Secure genetic resource base ++
Soil biological activity ++	Balanced nutrient cycles +	Water management ?	Secure mineral resource base (P) +
Soil toxin levels ++	Controlled waste disposal ++	Positive added value in foreign currency per unit of resource used in agriculture ++	Positive balance of payment in agricultural sector ?
Species invasion +	Efficient water use ++		Socially acceptable levels of contaminants in commodities +
Soil depth ++	Profitable enterprise, job satisfaction +	Survival and support of rural community +	

Species invasion +
Species invasion will not be controllable but will be manageable. Big invasions are unlikely because of the ecologically stable environment created over time and through spatial diversity. Existing ecological balances will not be disturbed by excessive use of agri-chemicals. The most likely disturbing factors will be climate and unpredictable environmental events.

Soil depth ++
Diversity of species, diversity of root depth and root distribution. Deep rooting, well-distributed

rooted crops are part of the crop rotation. This will develop the soil structure and depth to an optimum level for crop production. This is deeper than the tillage layer normally used for calculating fertiliser requirements).

Farm level

Biological and economical diversity ++

Here trade-offs will have to be made to meet the criteria for an optimal ecological crop rotation. It is not always sensible to use crops with the highest profits. The diversity that is needed to stabilise the agroecosystem is present so there is a biological as well as an economic balance.

Balanced nutrient cycles +

N, P, and K requirements are mainly met by balancing 'demanding crops' and 'giving crops' and organic farm wastes. Agronomists have different views about whether produce harvested from the land will eventually deplete the soil. Nitrogen requirements can easily be supplied by biological fixation. P and K can be bought in as organic wastes or as mineral dusts.

Controlled waste disposal ++

Waste production is low because agri-(bio)chemicals are not used. All organic wastes are recycled. Wastes will come from maintenance and cleaning of farm buildings and equipment. Problems through leaching of nitrogen during mineralisation are not high and can be reduced with the use of 'catch' crops.

Efficient water use ++

High soil stability created with the help of a high soil organic matter content improves soil structure and water retention capacity is optimal. Efficient water use is therefore dependent on the farmer's management skills. The soil is in optimum condition.

Profitable enterprises and job satisfaction +

Trade-offs have to be made between larger yields of a few highly profitable crops in a situation where rotation is not practised and lower yields of less profitable crops that may occur in a situation where crop rotation is practised. While the former may give greater short-term profit, crop rotation may achieve this over a longer term. It is difficult to make exact comparisons, since some crops grown in a rotational scheme may be less marketable at present because they are unfamiliar to the consumer. There is much to do to establish the commercial infrastructure and to encourage the consumer to diversify their tastes. There is, however, a global demand that exceeds supply for biodynamic and organic produce, and the future looks optimistic for growers of these products.

Catchment level

Water/air contamination +

The main water and air contaminants will come from the maintenance and cleaning of farm buildings and equipment, and fuel combustion. Leaching and losses from volatilisation will be very limited due to the ecological balance in the soil created by relatively high organic matter content in the soil. Fuel combustion through mechanisation of the cropping puts a constraint on the organic biological image. In future 'green technologies' based on wind or solar energy might be an option.

Water management?

Climatic stress imposes species boundaries in crop rotation. In dry areas 'trade-offs' would need to be made in the choice of crops and crop diversity. Crop rotation may not even be a suitable practice, in certain regions of the world where climatic extremes are experienced. The farmer must select crops that are well adapted to the region.

Positive added value in foreign currency per unit resources used in agriculture ++

Organic crop rotation can be seen as a low input production system that provides produce for a niche market. The demand for organic produce is rising each year and premium prices in Europe, Japan and USA are not exceptional.

Rural community survival and support +

Organic farming is establishing a better public image.. Rural communities could become partially self -sufficient and thus independent, through the diversity of crops and animal products produced by local organic farmers. It will stabilise rural communities.

Nation

Secure genetic resource base ++

Crop rotation has already increased the genetic resource. Shelter belts, natural corridors and forests in the neighbourhood of the farm would increase genetic diversity even further and stabilise the system. There will be a suitable environment for numerous species.

Secure mineral resource base +

Organics (and thus crop rotation) does not have a high demand on agri-chemicals. This means that mineral resources are secured.

Positive balance of payment in agricultural sector ±

This input system is likely to give a slight decrease in production. It will give a decrease in cash crops because the emphasis is on a broader range of crops, not just commercially attractive crops (as already described under

Profitable Enterprises). The challenge will be to find, or establish a suitable market for the maintenance crops grown in a crop rotation scheme, (for example, snap peas, endive and spinach).

Socially acceptable commodities +
Theoretically, biological diversity makes outbreaks of pest and diseases manageable as it creates unfavourable conditions for epidemic outbreaks. Balanced nutrients and minimal or no agri-chemicals should prevent or reduce environmental pollution.

Conclusion
The example chosen for this article suggests that well being at all the levels in the scheme is secured. It can be a sustainable practice. One can conclude that, in general, a well-designed and managed organic crop rotation can be relatively sustainable. It can certainly be more sustainable than most modern agricultural practices. This does not come as a surprise because the example of crop rotation I considered in this article was developed out of Steiner's concept that a farm is a living organism in a hierarchy of living organisms. On this farm **all** levels of the hierarchy have been considered in its design, while the designs of many modern farms fail to do so.

Although this has been a theoretical review of this farm, it does show us the capabilities of a 'systems' approach. Here is a tool that can support us. What we now have to do is gather the practical scientific data from our farm, assess it, make improvements and publish our results alongside conventional approaches.
I believe that if we are able to meet the challenges of conventional science, we can offer much that is worthwhile to the development of agriculture in the future.

I see it as part of our duty as conscious farmers to gather appropriate information both on the farm level and those levels below. As members of the Association we would then be able to contribute to the collation and integration of this information with the higher levels in the scheme I have described. In this way, the strengths of the biodynamic approach can be demonstrated and we can see areas where we need to make improvements.

This article is written to contribute towards a continuing developmental process.

(Continued from page 2)
beach to State Highway One. The mist still gathered on the tops and in the folds of gullies of the forested hills that form the western approaches to Akatarawa. The hills seemed as a sleeping giant, under mist blankets, splendid where their green cloaks of forest remained. When low winter sunsets bathe the hillsides, they are magically lit and ethereal in form, yet this morning was the first time that the hills revealed something bigger of their being. From the sleeping giant the descending broad flats to the 'beach' were once dense swamp forest, peat bogs and waterways, thick with flax and raupo, crossed by the meandering Waikanae River as it made its way to the ocean beach, changing its course dramatically over years. Now only a few forested patches remain between the luxuriance of the 'garden area' – its colour fabric changing through the seasons– and the sea.

The beach houses, anchored on dunes and the edges of swamp and stream, face the dynamic of the wind and ocean. Still nights, I can hear the mood of the sea reverberating - a gentle calm or still angry waves boiling over the broad shallow sandy shore. My house and garden stand three streets behind the ocean and though the "*Harvests*" office looks east to the hills, most of the rooms and the garden face the ocean. I live 'towards the west.' I can experience the slow creeping approach of rain over days, or the sprite like little shower that somehow just appears from a patch of blue sky and is then gone, or the rains that send the Ngarara and Waimeha streams to scour the golf course and litter the sea edge with white 'eggs'. In February, I hear the arrival of newly - fledged black - backed gulls from Kapiti, and on beach walks, watch caspian terns on their longshore fishing trips, or the whitebaiters netting on the rising tides. I meet the occasional furseal or sea elephant ashore from subantarctic wanderings, or find subtropical Portuguese Man o War, By the Wind Sailors and thousands of the little spiral shells of the tiny squid Spirula. Last year, even, a drift of several thousand mangrove propagules arrived! More tragically the storms bring the sea - wrecked prions, and petrels of many kinds. Amongst the drift washed from the rivers up the coast, I bring home punga logs for garden edging, scoria for the path, and pumice for garden and kitchen.

It was when the garden was fenced that I began to notice its growing individuality. I noticed when Tuis moved from neighbours' *Banksia* trees into 'mine' during the day. I began to notice the enormously long flowering season of that tree that allows me to watch the Tui , bumble bees and honey bees, feeding on the nectar, just metres from the kitchen bench. My biodynamic calendar became a weather record - but crowded with entries about Tui song, as I

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