Systems Thinking
– Key Concepts

1 What is a "system"?

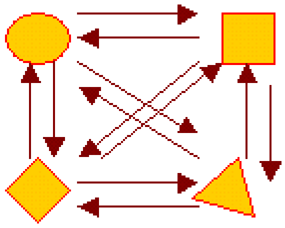
There are many definitions of a system. Taking elements from different definitions, we can say that a system is:

- An arrangement of physical components related in such a way that they act as a whole.
- Where the properties of the whole arise from the relationships between the component parts; and
- Something that has a purpose, or is of interest to someone.

A car can be described as a system, made of lots of bits that act together. If we take out the engine, the car does not work, nor do the wheels alone get us where we want to go. But a heap of spare parts is not a system, as they do not act together. Cars are of interest to us, because they can get us from place to place, and also because they can be fun to drive, or because they confer offer prestige or status.

A prison can be described as a system. If we take away the walls, or the warders, then it will no longer be a prison, and walls and warders by themselves do not constitute what we think of as a "prison". We think of prisons as having a purpose, but this purpose can be interpreted somewhat differently by different people: to some it may be way of keeping criminals off the streets, to others a way of punishing them, and to yet others a way of rehabilitating them. All these interpretations are similar, yet sufficiently different to imply different ways of managing a prison system

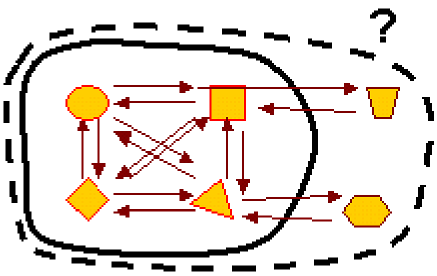
Natural systems, such as the "solar system" for example, may not have an obvious purpose. But once humans begin to modify or manage the system, it invariably becomes a “human activity system” and is given a “purpose” – even though different people might define that purpose in different ways. One could argue that there are essentially no “natural systems” left on earth. Even remote areas such as national parks, or even Antarctica, are now managed by humans.



There are many ways to represent systems in diagrams. This simple diagram shows components (boxes) and interactions (arrows). We will see other properties of systems below.

2 Properties of systems

2.1 Boundaries

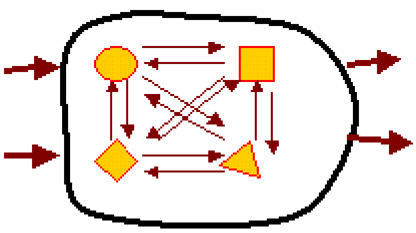


Deciding what is part of the system is not always straightforward. Are the vans that bring prisoners to the prison part of the system? Or the cells in the police station? Or the courts and judges? Deciding where are the limits or boundaries of the system are, which components are “in” and “out”, is therefore determined by the perspectives of those who choose to identify and define the system. Components outside the boundaries are said to be part of the “environment”.

In rural research and development, where we put the boundaries of a what we consider to be “the system” depends on and also determines which factors are considered to be amenable to intervention through project activities, and which are taken as unalterable (factors which can be changed are sometimes called “variables”, and those which are fixed “parameters”). Nevertheless, even if such external or environmental factors are outside our immediate control, they can still very much affect the system we are considering. Many research projects fail not because they do not implement the activities planned or change the internal factors, but because they do not consider the (changing) external factors and how the system will be affected by this changing environment.

2.2 Inputs and outputs

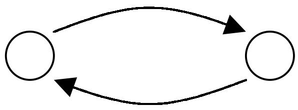
Few systems are totally “closed”. They normally have inputs and outputs. A car, for example needs petrol to produce movement.



Systems are often regarded as a means of transforming something – a set of “resources” or “inputs”- into something else – “products” or “outputs”. A field can be considered as a system that transforms seed, labour, nutrients, water and sunshine into a useful crop (although this is not the only way of looking at it).

2.3 Feedback

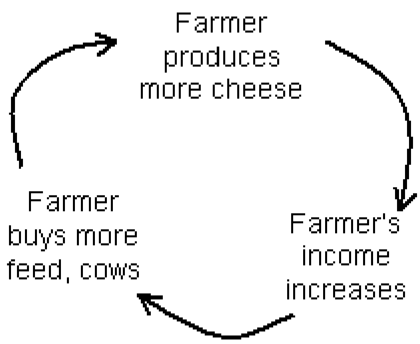
One of the characteristics of systems noted above is that the components interact. A change in one component or process causes a change in another component or process. Feedback occurs when the changes in the second component or process "feed back" to affect the first.



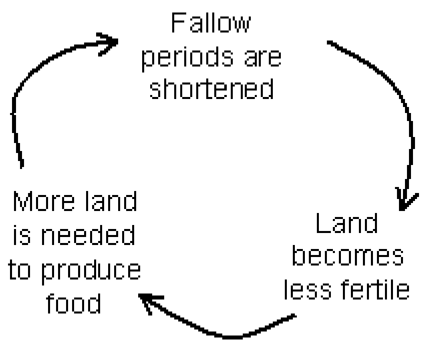
Such "feedback" may be **negative** (compensatory or balancing) or **positive** (exaggerating or reinforcing).

A simple example of negative feedback is a thermostat: the heater warms up the room, when the thermostat switches off the heater. Another example of negative feedback is weeding: more weeding leads to more crop growth, which then shades out new weeds and reduces the amount of further weeding needed.

Positive feedback can lead to both virtuous and vicious circles, depending if the outcome is considered to be good or bad.



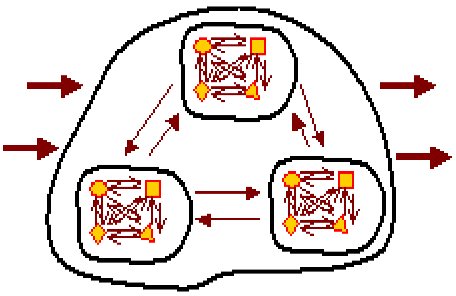
A "virtuous circle"



A "vicious circle"

In many complex systems, the effects of changes in one component or process may not always be predictable, and an intervention may even have the opposite effect to the one intended. An example is the use of insecticides in crops such as rice and cotton: at first the target pests are controlled, but the insect predators of the target pest are also killed, and when the target pest develops resistance to the insecticide, there is no natural predation and so pest infestations are then even worse than the original situation. Many development interventions have failed because of such unintended "feedback" between components of the system.

2.4 Hierarchies



When considering arrangements of things as systems, it soon becomes apparent that the individual components can usually be considered as systems themselves, and the overall system can also be considered as a component of a yet larger system. The "fuel injection system" could be considered a component of our car; and the car could be considered one component of a town's transportation system. We can therefore say that systems are arranged as **hierarchies**. A field or crop system can be considered as one component of a larger “farm system”, which can be considered to be part of a “village or community system”, which can be considered as part of a regional system, and so on. Usually, to understand how a particular system works, we need to understand the “higher” system (which forms and important part of the “environment” of our system), and also the “lower” systems (which form the components of our system.

The process of ARD in the last few decades has been one of gradually including or focussing on higher “levels” of the hierarchy. In the 1960s, the predominant projects and disciplines focussed on crop improvement and crop systems; in the 1970s, the attention moved to “farming systems”; in the 1980s and 90s, agriculture research recognised the need to work with groups of farmers and communities

2.5 Emergent properties

As we have seen, the properties of the overall system may be difficult to predict from looking at the different parts in isolation. The overall system has "emergent properties", or characteristics that appear at a certain level of complexity but do not exist at lower levels. Life is an emergent property of the human “body system”: components of the body do not show life on their own. Likewise, it is difficult to predict the performance of a farm by studying separately the crops, the animals – even the farmer. A team of people can be considered as a system, but sometimes the performance of the overall team is difficult to predict from looking at the individual members in isolation.

3 What is “systems thinking”?

Systems thinking, or “systemic” thinking, is thinking about the whole instead of the parts. The emergent properties cannot be observed or changed by studying or taking action at the level of individual components. Systems thinking means giving emphasis to the relationships between the different components, rather than just looking at the components in isolation. Systems thinking also means taking into account the context, circumstances or environment that surrounds the particular system being studied, so “systems thinking” is also "contextual” thinking - understanding the system within the context of a larger whole. Some people also call this “holistic” thinking.

3.1 How does systems thinking differ from conventional thinking?

All of us think in different ways. People from “western” societies tend to think differently than people from “eastern” cultures. Women think differently than men. Because of their education and training however, scientists and technicians are particularly likely to think in what can be regarded as “conventional”, “mechanistic” or “reductionist” ways. Although few people think in entirely one way or the other, the following table contrasts the two ways of thinking:

Conventional Thinking	Systems Thinking
Concentrates on the parts themselves	Concentrates on the interaction of the parts and organization
Does not recognize feedback	Recognizes the importance of feedback both positive and negative
Follows a linear direction, logical step by step	Open minded, unstructured with no set direction
Follows ideas related to causes and effects.	Captures the variety of ideas.
Looks for a dominant perspective or point of view – the "right" one.	Takes account of different opinions and points of view.

3.2 Different perspectives

When people see a common situation, individuals are likely to recognise different "systems" because they have different perspectives. When we see a situation we see it through the eyes of our own culture, our own special experiences, our own educational background and especially our disciplinary bias, and our own special ability to think. In systems, the combination of our culture, experiences, education and thinking skill is often expressed as "a perspective". Our perspectives can be quite different; even when we are looking at the same physical world.

These differences of perspective and ways of conceptualising the system lead to differing interpretations of the *performance* or even the *purpose* of the system. The agronomist for example, may see the farm as a system for producing grain for home consumption. The livestock scientist may see a system for helping to reduce milk imports. The ecologist may see part of a wider system for supplying water within a particular catchment area. The economist may see a system for reducing rural poverty through increasing farm income, and so on.

3.3 Problems and problem situations

The management of natural resources and agriculture is a complex human activity. As we have seen, the complexity is often made more difficult and confusing by the different perspectives held by different people of any given situation.

It is helpful to distinguish two types of unsatisfactory situation:

- A simpler "problem", where there are generally few people involved, few complicating factors; and where there is general agreement about what is wrong and what constitutes a "solution".
- A more complex "problem situation" or what the systems thinker Russel Ackhoff simply called a "mess", which can be viewed as a situation which most people agree is unsatisfactory in some way, a set of often interrelated but undefined or poorly defined problems about which there is little agreement as to what needs to be done, or even what would constitute and improvement. Usually, the coordinated actions of several different people or

groups of people, often over a longer timescale, are needed to make significant and lasting improvements to the situation.

As agricultural researchers and development professionals, we often think we know what the problem is, only to find out that others see the situation differently. They may see other related problems as more important, or see our proposed solutions as unworkable. For example, we may see agroforestry as a good solution to the poor soil fertility status of crop lands, but the women responsible for growing food crops will see it differently if they have no control over land use and hence are not allowed to plant trees. Or we might think applying the stable manure to the fields is a good idea, but the farmers might think that part time employment as labourers in a local town is a better use of their time.

An initial stage in ARD is therefore the sorting out of the problem area and the objectives of the research. In practice, this means gathering information about how different stakeholders – people who have a stake or interest in the matter – see the problem situation. It also means a taking a wider look at the issues, the context within which our initially identified problem occurs. Gathering the diverse views of stakeholders and a taking a wider look often then results in a redefinition of our "central" problem, research question or system of interest – and a whole new area for finding "improvements" to this system.

4 Acknowledgments

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