CHAPTER 2

Farming systems and sustainability

This chapter sets the scene for the rest of the report. It explains important concepts associated with farming and sustainability. It defines key terms such as 'natural capital' and discusses why the development of more intensive farming systems can be a cause for concern. It also identifies some key principles of sustainable agriculture.

2.1 Farming systems

2.1.1 Taking a systems perspective

A farm is a place where agricultural activities occur to produce food and/or fibre from plants and/or animals. Each individual farm can be thought of as a system in its own right — a modified ecological system that includes people, crops and livestock within a broader environmental, social and economic context.[1] It is essential to take a systems perspective when examining farming and sustainability. This allows us to understand the reasons behind unsustainable practices and to develop long-term solutions to problems.

A systems perspective involves looking at the biophysical dimensions of farming (such as nutrient and water cycles) as well as socio-economic aspects (for example, social values and institutional structures). Farms can be analysed as systems from various points of view, depending on the scale of analysis. As Feenstra *et al.* note:

> ***The system is envisioned in its broadest sense, from the individual farm, to the local ecosystem, and to communities affected by this farming system both locally and globally. An emphasis on the system allows a larger and more thorough view of the consequences of farming practices on both human communities and the environment. A systems approach gives us the tools to explore the interconnections between farming and other aspects of our environment.[2]***

Farming systems, in the context of this report, therefore range from individual farms through to the broader social and economic structures and institutions linked to farming. Although the major focus of this report is on the farming end of the food chain (see Chapter 1), it is also important to consider the place of farms in broader food systems that include many other organisations and people, such as producer boards, retailers and consumers of food.

2.1.2 Intensive farming systems

'More intensive' refers to the increasing use of inputs into farming systems to produce more food from the same area of land.

Farming in New Zealand is becoming more intensive. 'More intensive' refers to the increasing use of inputs (e.g. fertiliser, energy, water for irrigation, knowledge or capital) into farming systems to produce more food from the same area of land.[3] Intensive farming is usually characterised by the repeated cultivation and/or grazing of land and the addition of a large number of inputs per hectare to maintain or increase production every year.[4]

Over the last century, especially since the 1940s, there has been a general worldwide trend to increase food production through the addition of external human-made inputs into farming systems. These include petroleum-based fertilisers, chemical pesticides, animal

feedstuffs and machinery. These inputs have often taken the place of natural processes or resources (e.g. using synthetic fertilisers instead of legumes to 'fix' nitrogen into the soil). Although food production has increased remarkably through the use of these inputs, major concerns have been raised about the long-term environmental, social and economic costs of these farming methods. Prominent issues have included the erosion of topsoil, loss of soil fertility, water pollution, loss of biodiversity and dependence on non-renewable fossil fuels.[5] Worldwide, there have also been growing concerns about the adverse impacts of intensive farming systems on food safety, human health, the viability of small family farms and the quality of life in rural communities.[6]

It is important to note that 'more intensive' is a relative phrase, in the sense that something is increasing in relation to what it was. While many farming systems are becoming more intensive in New Zealand (see Chapter 3), farming in this country is not generally as intensive as many farming systems in North America and Europe. Intensification occurs along a continuum from relatively low external inputs (such as pastoral farming systems that do not use synthetic fertilisers) to those that rely on very high external inputs (such as factory farming).

It is important to emphasise that there are many different ways in which farming systems can be designed to produce more food. For example, it is possible to make more use of human knowledge to increase food production while using less material and energy inputs.[7] It is the particular *way* in which more intensive farming is carried out that needs to be considered in any discussion on sustainability.

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2.2 Sustaining natural capital

2.2.1 Natural capital and ecosystem services

The concept of 'natural capital' is pertinent to the sustainability of intensive farming in New Zealand. This concept has developed along with more widespread understanding of the fact that economic development does not just depend on financial capital — it ultimately relies on many other forms of 'capital' as well. These have been defined as:

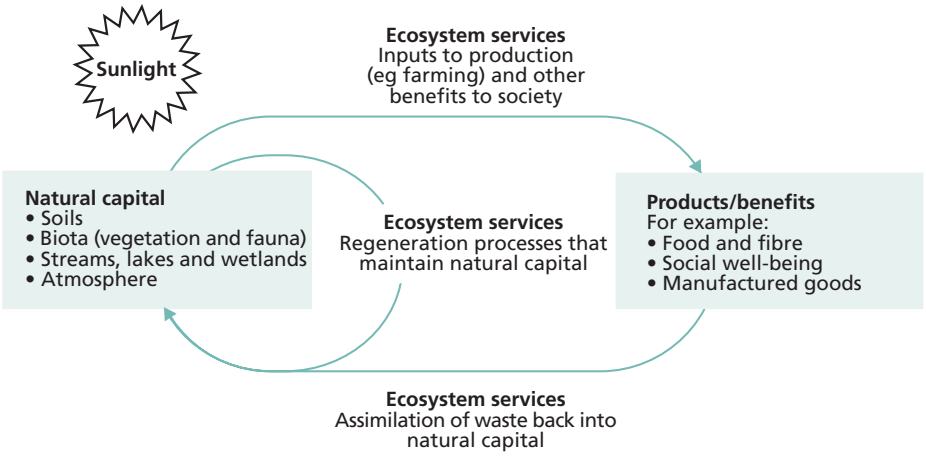
- *natural capital* — the renewable and non-renewable stocks of natural resources that support life and enable all social and economic activities to take place. It includes rivers, lakes and aquifers, soil, minerals, biodiversity and the earth's atmosphere.[8]
- *economic capital* — the human-made means of production like machinery and equipment as well as infrastructure and financial assets.
- *social capital* — the networks of shared norms, values and understanding that facilitate co-operation and trust within and between groups.
- *human capital* — the knowledge, skills, competencies and attributes embodied in individuals that are developed through lifelong learning and experience, including through the formal education system.

- *cultural capital* — the values, histories, traditions and practices that link a specific group of people together.
- *institutional capital* — the range of formal and informal civic, political, and legal arrangements that underpin economic activities and civic life.[9]

There are sometimes debates about the extent to which human forms of capital can take the place of natural capital.[10] Nonetheless, natural capital provides many services that are essential to human life. These 'ecosystem services' include clean air and water, the creation and maintenance of fertile soils, pollination, the regulation of liveable climates, raw materials, genetic resources for harvesting and growing food and fibre, and processes to decompose and assimilate waste.[11] Although these services are often taken for granted, they have immense social and economic value. Many of these services are indeed priceless, as they have no known human designed substitutes.

Figure 2.1 highlights the relationship between natural capital and ecosystem services. Humans use natural capital, such as soil and water, for production purposes like farming and to provide things they value. To regenerate and to remain in a healthy condition, natural capital relies on sunlight and many ecosystem processes that are interdependent. Waste and by-products from production and consumption always remain within the environment. This waste can have a positive or a negative impact on the state of natural capital, depending on the type of waste and the capacity of the environment to assimilate it. In turn, this can affect the ability of natural capital to provide ongoing benefits to society.

Figure 2.1 Natural capital and ecosystem services



Source: Adapted from Binning *et al.* (2001).

... human societies need to live off the 'interest' of natural capital, instead of using up or degrading the natural resource base

It is also possible for humans to maintain or enhance the condition of natural capital. For example, soil fertility can be enhanced by recycling nutrients back into the soil. By thinking about the environment as a form of capital, the analogy is often made that human societies need to live off the 'interest' of natural capital, instead of using up or degrading the natural resource base that sustains human societies.

2.2.2 Criteria for environmental sustainability

The central focus of this report is on the *environmental* sustainability of farming in New Zealand—i.e. maintaining and enhancing natural capital and the services it provides. Environmental sustainability, as defined by the Organisation for Economic Cooperation and Development (OECD), has four specific criteria. These can easily be applied to thinking about the sustainability of farming systems, as listed below:

- *regeneration* — using renewable resources efficiently and not permitting their use to exceed their long-term rates of natural regeneration (e.g. taking water from an aquifer at a rate that does not exceed its recharge rate)
- *substitutability* — using non-renewable resources efficiently and limiting their use to levels that can be offset by substitution by renewable resources or other forms of capital (e.g. using fossil-fuel based fertilisers efficiently and developing human capital to find alternative ways of maintaining soil nutrients)
- *assimilation* — not allowing releases of hazardous or polluting substances to the environment to exceed the environment's assimilative capacity (e.g. preventing excess nutrients entering waterways)
- *avoiding irreversibility* — avoiding irreversible impacts of human activities on ecosystems (e.g. ensuring that farming does not contribute to the extinction of a plant or animal species).[12]

Environmental sustainability is also essential for sustainable development—an unending quest to improve the quality of people's lives and surroundings and to prosper without destroying the life support systems that current and future generations of people depend on. A detailed discussion on sustainable development can be found in the Commissioner's investigation *Creating our future: Sustainable development for New Zealand*.[13] As that report emphasises, it is important to recognise that there are ecological limits that ultimately constrain resource use and the ability of the environment to absorb the impacts of human activities.

2.2.3 Natural capital and farming

A farm is a modified ecosystem that exists within a broader environmental, social and economic context. Although farming in New Zealand is based on introduced species, it still relies on the services provided by natural capital to sustain production. Farming activities can have an impact on natural capital in many ways. As the OECD notes:

> ***Agricultural activities can generate a range of environmental benefits. These include aesthetic value, recreation, water accumulation and supply, nutrient recycling and fixation, soil formation, wildlife protection and flood control, and carbon sequestration by trees and soil. However, major changes in farming practices in the past forty years have brought new pressures to bear on natural resources.[14]***

Some potential negative effects of farming include:

- *declining soil fertility and integrity* — e.g. through erosion of soil or the loss of organic matter
- *pollution of waterways and groundwater* — e.g. impacts on water quality from nutrient losses
- *water scarcity* — e.g. through competition with other water users by extracting excessive amounts of water for irrigation
- *reduced biodiversity* — e.g. becoming reliant on a small number of crop and livestock breeds through the development of monocultures that are more vulnerable to pests and diseases
- *climate change* — e.g. contributing to the loss of vegetation (important 'carbon sinks') or increases in greenhouse gas emissions.[15]

These impacts may occur across different scales of space and time. For example, nutrient runoff from one farm may impact on water quality and all other water users downstream, while the cumulative impacts of groundwater pollution from farming practices on lakes and waterways may only become slowly evident over time.

As farming relies so much on ecosystem services, it is important to have a basic understanding of some ecological processes that maintain natural capital. These include nutrient cycling, the water cycle, and energy flow, each explained briefly below.

Nutrient cycling — Nutrients are components required for normal growth and development. Plant roots take up nutrients such as nitrogen, phosphorus and potassium from the soil. Plants photosynthesise, converting water, carbon dioxide and minerals into organic material, using energy provided by the sun. Unable to utilise the sun's energy directly, animals depend on organic carbon sources for their energy, and hence consume plants or other animals. Energy flows one way through an ecosystem (see below), but materials like water, carbon dioxide and nutrients circulate within and between ecosystems. Decomposers, such as soil bacteria and fungi, break down dead plant and animal matter, absorbing some substances and releasing some back into the environment for uptake once more by plants. When plants or animals die in natural ecosystems, nitrogen and other nutrients are cycled back into the soil. However, in agricultural ecosystems, plant or animal biomass is removed with harvesting, and fertiliser is added to the soil to supply essential nutrients for plant growth.

The water cycle — Water cycles between the atmosphere and earth, condensing and falling as precipitation. It then flows over ground and into streams and lakes and out to sea, or filters down through the ground, nurturing plants and recharging groundwater. It moves back to the atmosphere *via* evaporation and plant transpiration, to be condensed again, thus continuing the cycle. Around 94 percent of the Earth's water is found in the oceans, four percent occurs as groundwater, 1.6 percent as ice at the Earth's polar caps, and 0.2 percent occurs either as water vapour, in clouds, in unsaturated soils, or in plants and animals. Only 0.2 percent occurs as surface water, i.e. in rivers and lakes. Fresh water, a finite resource, is essential to farming for pasture and crop growth and for livestock.

Energy flow — The lifeblood of any ecosystem, energy flow begins when sunlight is converted by photosynthesis into plant growth. It continues when animals consume plants or other animals and when micro-organisms consume dead plants and animals. Rather than relying wholly on the sun for energy (as would occur in a natural ecosystem), agricultural ecosystems also rely on energy inputs that are principally derived from fossil fuels. These are accumulated stocks of previous solar energy flows — energy rich compounds found below ground.[16] Energy efficiency in agricultural systems can be examined by looking at the ratio of energy inputs to energy outputs. The lower the energy ratio, the more efficient the system and the lower the environmental impact, because the system relies more on natural ecosystem services and less on fossil fuel inputs. Energy efficiency declines when synthetic inputs are used instead of natural forms of pest control, fertiliser and water retention.[17]

It is essential to maintain natural capital in a healthy condition. If natural capital is degraded, the ongoing viability of farming may also be threatened. Degraded natural capital is currently contributing to decreasing farm productivity in many parts of the world, regardless of technological measures to try and alleviate these problems.[18] As the Ministry of Agriculture and Forestry commented over a decade ago:

> ***There is growing concern worldwide about the state of the natural environment and whether agricultural productivity can be sustained. It is not only good environmental practice, but sound economic sense to preserve the base on which our livelihood as a country depends.***[19]

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Many other economic sectors also rely on New Zealand's natural capital and the '100% pure' imagery that is used to sell New Zealand products or services to the world. The wealth generation capabilities of New Zealand as a whole will suffer if environmental realities do not meet the expectations of overseas consumers or tourists.

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It is also important to recognise that the vast majority of New Zealanders value living in a high quality environment.[20] Natural capital provides many social and economic benefits beyond the farming sector. If farming has an adverse impact on water quality, this may affect drinking water supplies and fisheries. If other individuals, organisations or communities regard the environmental damage from farming as unacceptable, farmers are likely to lose their 'licence to operate' in society.

Soils: the central engine room

> *We can no more manufacture soil with a tank of chemicals than we can invent a rain forest or create a single bird.*[21]

To illustrate how degraded natural capital can threaten the viability of farming, it is useful to consider the vital role of soil in farming systems. Soil provides the medium in which many of the ecological processes discussed in this section occur. It is a precious non-renewable (in human time scales) limited resource, holding life-supporting minerals, water,

air and countless organisms—all of which facilitate plant growth. Soil ecosystems are extremely complex and small scale, and scientists still have much to discover in understanding how they function. As Young and Crawford note:

> *Given its importance, it is surprising how little we know about our most important natural resource. Indeed, much about soil remains a mystery, yet probably presents us with the most important clues as to how complex ecosystems become capable of self-organisation and sustaining functionality. Pick up a handful of soil and ask the question 'what is in it?' and an exciting new journey into inner space begins. In fertile garden or organic soil, there will be more individual organisms than the total number of human beings that ever lived.*[22]

After taking thousands of years for fertile soil to form, agricultural practices can undermine this most fragile yet fundamental form of natural capital in a short time *via* erosion, compaction, loss of organic matter, contamination and salinisation.

2.3 Sustainable agriculture

There has been considerable debate, over the last few decades in particular, about how farming can be conducted in ways that maintain natural capital.[23] 'Sustainable agriculture' is the term most commonly used to bring ideas and concepts from these debates together. The dialogue on the sustainability of farming has also focused on social and economic concerns such as the viability of small family farms, the quality of life in rural communities, animal welfare issues, poverty and food shortages in developing countries.

There is no single agreed upon definition of sustainable agriculture, but most definitions incorporate three main elements — environmental sustainability, social acceptability and economic viability. The definition of sustainable agriculture adopted by New Zealand's Ministry of Agriculture and Forestry is:

> ***...the use of farming practices which maintain or improve the natural resource base of agriculture, and any parts of the environment influenced by agriculture. Sustainability also requires that agriculture is profitable; that the quality and safety of the food, fibre and other agricultural products are maintained; and that people and communities are able to provide for their social and cultural well-being.***[24]

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One of the challenges in the quest for more sustainable agriculture is to make better use of internal resources, while being less dependent on external inputs. There has been a general trend over the last century to increase food production through the addition of external human-made inputs into farming systems. These external inputs have often taken the place of free services provided by natural capital. Table 2.1 compares farming systems that mostly use local resources with those that rely more on external inputs. Making better

use of internal resources does not mean that 'conventional' farming practices should be rejected — it merely highlights the importance of being discerning. At the level of an individual farm it may actually be more profitable to use fewer external inputs, even if overall production is lower, because external inputs are often very expensive.

Table 2.1 Comparison of internal and external resources/processes for farming

	Internal	***External***
Sun	Main source of energy	Supplemented by fossil fuels
Water	Mainly rain and small irrigation schemes	Large dams, centralised distribution and deep wells
Nitrogen	Fixed from the air and recycled in soil organic matter	Primarily from inorganic fertiliser
Minerals	Released from soil reserves and recycled	Mined, processed and imported
Weed and pest control	Biological, cultural, mechanical and locally available chemicals	With pesticides and herbicides
Energy	Some generated and collected on farm	Dependence on fossil fuel
Seed	Some produced on farm	All purchased
Management decisions and information	By farmer and community, gathered locally and regularly	Some provided by input suppliers, researchers, extensionists – assumed to be similar across farms
Animals	Integrated on farm	Production at separate locations
Cropping system	Rotations and diversity	Monocropping
Varieties of plants	Thrive with lower fertility and moisture	Need high input levels to thrive
Labour	Labour requirement greater – work done by family living on farm and hired labour	Labour requirement lower – most work done by hired labour and mechanical replacement of manual labour
Capital	Initial source is family and community; and accumulation invested locally	Initial source is external indebtedness or equity; and accumulation leaves community

Source: Pretty, 1995: 10

Sustainability can be thought of as an ethic or a general approach to farming — something to strive toward to promote the continuing health of the land and people. The actual *practices* of sustainable agriculture need to be tailored to the unique biophysical features (e.g. different climates and soil types) and the socio-economic characteristics and cultures of different communities. As Clay suggests:

> ***There is no single 'right' way to practice more sustainable agriculture. Many farmers have found ways to reduce environmental damage, improve production, and increase profitability. How the farmers do this depends tremendously on where they live, what they produce, and where they sell the product. Broadly speaking, though, farmers are beginning to invent, adapt, and adopt a wide range of approaches that are usefully seen as 'better management practices'. Such practices involve maintaining and building soils, maintaining the natural ecosystem functions on farms, working with nature and not against it to produce products, reducing total input use and using inputs more efficiently, and reducing waste or creating marketable by-products from materials that were previously considered waste.***[25]

... 'strong sustainability' requires people to address the underlying social, cultural, and economic reasons that rest behind environmentally unsustainable practices.

As highlighted in *Creating our future*,[26] 'strong sustainability' requires people to address the underlying social, cultural, and economic reasons that rest behind environmentally unsustainable practices. In particular, it is essential to avoid making trade-offs between environmental and economic objectives if short-term economic benefits later give rise to long-term damage to natural capital and associated costs to society. It is important to redesign social and economic systems if there is evidence that they are encouraging farmers to pursue environmentally unsustainable practices.[27] In contrast 'weak sustainability' is characterised by attempts to reconcile competing environmental, social, and economic objectives without questioning the prevailing socio-economic systems.

2.4 Summary and key principles to promote sustainable agriculture

We have identified some key principles to promote sustainable agriculture.[28] These principles have guided the thinking throughout this report. Ultimately, farming needs to be:

- *environmentally sustainable* — to maintain and enhance the natural capital on which farming depends as well as other ecosystems influenced by farming
- *socially beneficial* — to enhance the quality of life for people in rural communities and beyond, while addressing wider social and cultural concerns
- *economically viable* — to ensure farmers have a secure and rewarding livelihood.

These outcomes can be supported through the development of farming systems that are:

- *knowledge intensive* — investing in human knowledge to develop smart and productive farming systems that are less dependent on high levels of material and energy inputs
- *innovative* — experimenting and making greater use of farmers' knowledge, in combination with appropriate technologies developed through research
- *resource efficient* — using renewable and non-renewable resources efficiently and making the most effective use of natural processes and resources available on the farm
- *cyclical* — integrating natural processes such as nutrient cycling and soil regeneration into farming practices and using the by-products/wastes from farming as inputs into further production
- *high value* — producing high quality products from a quality environment
- *diverse* — developing and adapting farming systems so that they are appropriate for the local environmental, social, cultural and economic conditions
- *resilient* — developing the capacity of people to learn and adapt to changing circumstances, while ensuring that natural capital is still maintained.[29]

Decision-making for the development of more sustainable farming systems should be based on:

- *systems thinking* — taking an integrated approach that considers the interactions and relationships among different elements. It is necessary to address the underlying reasons that rest behind unsustainable practices instead of just treating short-term symptoms.
- *futures thinking* — maintaining a long-term perspective and anticipating risks and challenges to farming systems, including the future implications of existing practices. Past trends do not dictate destiny, so it is important to explore different visions for the future and to constantly look for opportunities to improve sustainability.
- *participation* — actively involving farmers and other people in rural communities to develop more sustainable farming systems. It is also important to encourage individuals and organisations that are part of broader food systems, and those affected by farming, to take part in finding sustainable solutions.
- *leadership* — supporting good participation through good leadership. It is essential to help people see any issues and opportunities ahead and to develop their capacity to seek out solutions.

With regards to the actual *techniques* of sustainable agriculture, the application of these principles in practice needs to be *site specific* — i.e. adapted to a specific farm or catchment based on the particular characteristics of that area and its people. Farming systems, and the socio-economic structures and institutions that shape them, also need to be *redesigned* if it becomes clear that they are contributing to environmentally unsustainable outcomes.