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Capital Based Sustainability Indicators as a Possible Way for Measuring Agricultural Sustainability

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1 Sustainable Development

The most frequently quoted and perhaps most widely accepted definition of sustainable development is the one articulated by the Bruntland Commission – development that 'seeks to meet the needs and aspirations of the present without compromising [the] ability to meet those of the future' (WCED 1987, p. 43).

Various disciplines have addressed the interpretation of sustainability in very broad terms. It is not uncommon, for example, to distinguish 'social sustainability', 'cultural sustainability', 'environmental sustainability', and of course 'economic sustainability'. Social sustainability includes key concepts such as resilient communities, sustainable livelihoods, and access to core services of education and health. Cultural sustainability includes language, values and cultural aspirations. Environmental and economic sustainability are key concepts in this paper and are presented in more detail below.

Four decades into talks and negotiations over 'sustainable development' as a planetary aim, and there still remain two key challenges in moving sustainable development from concept to action. One, the broad range of interpretations of the term and two, somewhat connected to the first, is the lack of reliable tools of measurement that can provide an indication if we are moving in the right direction in achieving sustainability.

1.1 The Capital Approach to Sustainability

Robert Solow's 1974 presidential address to the American Economics Association was devoted to the question of economic and environmental sustainability. Solow, the originator of modern growth theory in economics, defined economic sustainability as 'non-declining per-capita human well-being (utility) over time'. Note that his definition emphasised 'well-being', not 'income'. At about the same time, Hartwick interpreted sustainability as non-declining consumption over time (Hartwick 1977), which is now often referred to as the Hartwick–Solow condition for sustainability. This requires 'a non-declining capital stock over time' (Solow, 1986, and Repetto, 1986) where capital stock is understood in its broadest terms to include human capital, social capital, cultural capital, human-made capital and natural capital.

Human capital includes knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being. It is created through lifelong experience as well as formal education. Social capital has been defined as the 'network of shared norms, values and understanding that facilitate co-operation within and between groups' (OECD 2001). Cultural capital is the set of values, history, traditions and behaviours that link a specific group of people together. It can be particularly important where a minority culture exists alongside a dominant majority culture, e.g., Welsh in the United Kingdom; Québécois in Canada and Māori in New Zealand. Human-made capital refers to public and private capital such as buildings, factories, office blocks, plant and machinery, computers, infrastructure, airports, seaports, highways, roads, railways, schools, hospitals, the courts, telecommunication networks, and electricity networks. Many of these are either under the direct or indirect influence of local government.

Natural, or environmental, capital in economics is generally classified into three types: extractive resources such as soils, minerals, forests, fish and water; amenity values (direct and indirect) such as landscapes, native bush, recreational fishing; and assimilative capacity or the ability of the environment to 'process' waste pollution. Natural capital is different from the other types of capital discussed in the previous paragraph because of the irreversibility of some forms of natural capital when used. This leads to 'well-being' rules on its use that may include using renewable resources in a way that the harvest rate is not more than the renewal rate or keeping waste flows within the assimilative capacity of the local environment (Pearce, 1988). This is particularly important for stock natural resources that do not renew themselves (e.g. coal, oil). One rule for stock resources is that planners and/or policy makers should ensure that reductions in the stock are compensated for by increased investment in renewable resources or other forms of capital (Hartwick, 1977). Of course, this assumes there is substitutability between stock resources and other capital (Solow, 1974), an assumption that is not universally accepted (for example see Daly, 1996, pp. 76-80).

Another factor in assessing natural capital (and indeed other forms of capital) is the multi-functionality of this capital and hence whether all the associated benefits are properly assessed. This is related to the stability and/or resilience of the natural system, resilience being the ability of an ecosystem to maintain itself when shocked by natural or human disturbance. Sustainability therefore requires that human interactions with the environment should consider the impact on ecosystems as a whole rather than just on resources themselves with care to avoid threatening the stability of the ecosystem (Common and Perrings, 1992).

All the above forms of capital, including natural capital, can be enhanced by technological development. A constant or growing standard of living is assumed possible from a reduced set of natural resources through technical advances and/or greater efficiency, which is why governments pay such attention to fostering innovation in their industry and higher education policies.

Within economic thinking it has been an important point to view capital as having two aspects in reference to time – stocks and flow. This was described by Fisher (1896, p. 514) as follows:

> *'Stock relates to a point of time, flow to a stretch of time...The total capital in a community at any particular instant consists of all commodities of whatever sort and condition in existence in that community at that instant [i.e. capital stocks], and is antithetical to the streams of production, consumption and exchange of these very same commodities [i.e. capital flows].'*

1.2 Human-Made Capital

Human-made capital 'includes fixed assets that are used repeatedly or continuously in production processes for more than one year' (United Nations, 2008, p. 49). Such assets include tangible things 'such as machinery, buildings, roads, harbours and airports' and stocks of 'raw materials, semi-finished and finished goods held for future sale' and intangible types 'such as computer software' and telecommunications (ibid. p. 49). 'The value of produced capital is recorded in the balance sheet accounts of the national accounts' (ibid. p. 49) but also in accounts of firms and farms.

1.3 Natural Capital

In general natural capital is regarded to consist of three key categories: natural resources, land and ecosystems (United Nations et al., 2003 and United Nations, 2008). All three categories are critical for 'the long-term sustainability of development' because of 'their provision of "functions" to the economy, as well as to mankind outside the economy and other living beings' (United Nations et al., 2003, p. 5). These functions may be categorised as follows:

i. ***Resource functions*** – resources that are extracted from nature such as 'mineral deposits, timber from natural forests, and deep sea fish' for use within economic production systems and are 'converted into goods and services for the benefit of' humankind (United Nations et al., 2003, p. 5).

ii. ***Sink functions*** – nature's ability to 'absorb the unwanted by-products of production and consumption' through three naturally occurring destinations that are typically referred to as sinks – the atmosphere, water (including the ocean) and land. For instance, 'exhaust gases from combustion or chemical processing' are vented into the air, 'water used to clean products or people' are released into waterways that end up in the ocean, and 'packaging and goods no longer wanted' are 'buried in landfill sites' (United Nations et al., 2003, p. 5).

iii. ***Service functions*** – the aspects of nature that make up 'the habitat for all living beings including' humankind. These functions may be subdivided into two broad categories: (a) *survival functions* which comprises aspects of the habitat that are critical for the survival of biological beings such as oxygen and water and (b) *amenity functions* such as beautiful landscapes which do not determine survival but are valued for their function. This can be use value or non-use value.

1.4 Human Capital

According to the United Nations (2008) the term human capital does not yet have a standard definition. For example in one definition, human capital is seen as 'the stock of economically productive human capabilities' which stresses the economic worth of these capabilities (Bahrman and Taubman in World Bank, 2006, p.89; cited in United Nations, 2008, p. 51). In an OECD report the term was defined as the 'knowledge, skills, competencies and attributes embodied in individuals that facilitate the creation of personal, social and economic well-being' (OECD, 2001, p.18) – a definition which places a greater emphasis on the well-being aspects of peoples' capabilities (United Nations, 2008). Nevertheless, there is a link between the two areas of emphasis. For instance, a worker who is happy is likely to be more productive and 'a healthy worker will be happier as well as more productive' (Ekins, 2000, p. 55). 'Today, the economic importance of knowledge and skills is widely recognised both within labour economics, growth theory and business economics. At the same time, many see the personal and social well-being effects of learning as being as important as the economic ones' (United Nations, 2008, p. 51).

Within a more confined definition, human capital may be regarded as 'the stock of educated and experienced workers in the economy, and labour is the output [or capital flow] of this stock' (Smith et al., 2001, p. 7). A broader definition would describe human capital as an individual's capability to carry out work, which in turn is dependent on his or her education, knowledge, experience, skills, happiness, health status, and motivation to work. For example, workers who contribute to the agricultural sector include field workers (farmers, growers and their employees) and those who contribute somewhat such as agricultural researchers and government officials. Therefore human capital within agriculture may be defined to include the years of field level experience in agriculture, variety and levels of academic qualifications in agriculture, variety and levels of agriculture-related technical skills, the communication and interpersonal skills of farm managers, the status of farm workers' health and their level of motivation.

1.5 Social Capital

'The notion of social capital is the most recent addition to the capital approach' (United Nations, 2008, p. 52). Human capital is different from social capital. While the former entails features embodied in individuals (as discussed in the sub-section above), the latter descends from the manner in which individuals interact (Ekins, 2000). However, despite 'a considerable amount of research and attention devoted to social capital in recent years, there remains a lack of agreement around a precise definition of the concept' (United Nations, 2008, p. 53). Since the 'social capital' concept originates from sociology, it has largely focused on 'identifying the positive elements of society to be conserved and further developed' (United Nations, 2008, p. 52). There has been a broad range of proposed 'theoretical approaches for conceptualising social capital' and these approaches often overlap 'and range from the distribution of basic goods, to the maintenance of social peace, to social protection and constitutional goals, to networks and associated norms' (ibid., p. 52).

Goodwin (2003, p. 1) described social capital as 'the most controversial and the hardest to measure'; nevertheless it may be regarded to consist 'of a stock of trust, mutual understanding, shared values and socially held knowledge'. Ekins (2000, p. 55) suggested that social capital also has 'a direct relationship with welfare'. For instance, the states of social structures such as the family 'are major determinants of welfare' and the state of welfare of individuals in turn may 'affect the performance of social structures' (ibid., p. 55). The OECD (2001, p. 41) adopted the following definition of social capital: 'networks together with shared norms, values and understandings that facilitate co-operation within or among groups. Networks relate to the objective behaviour of actors who enter into associative activity. Shared norms, values and understandings relate to the subjective dispositions and attitudes of individuals and groups, as well as sanctions and rules governing behaviour, which are widely shared'.

Within the context of sustainability the term social capital suggests that 'social bonds and norms' are necessary for sustainability-related endeavours (Pretty, 2003, p. 1912) For instance where there exists a significant stock of social capital within a community or within formalised groups, people are more likely to 'have the confidence to invest in collective activities, knowing that others will do so too' (ibid., p. 1912). Within such a community, people 'are also less likely to engage in unfettered private actions with negative outcomes, such as resource degradation' (ibid., p. 1913). Four features of social capital that are important for sustainability aims are: 'relations of trust; reciprocity and exchanges; common rules, norms, and sanctions; and connectedness in networks and groups' (ibid., p. 1913). 'Relations of trust lubricate cooperation, and so reduce transaction costs between people. Instead of having to invest in monitoring others, individuals are able to trust them to act as expected, thus saving money and time. But trust takes time to build and is easily broken. When a society is pervaded by distrust or conflict, cooperative arrangements are unlikely to emerge. Reciprocity increases trust, and refers to simultaneous exchanges of goods and knowledge of roughly equal value, or continuing relations over time. Reciprocity contributes to the development of long-term obligations between people, which helps in achieving positive environmental outcomes' (Pretty, 2003, p. 1913).

At the farm level, the social capital stock of relationships of trust between farmers and institutions (including government agencies) interested in progressing sustainable agriculture appears essential for flow effects such as the exchange of information and the acquirement of knowledge that can facilitate the adoption of sustainability practices at the farm level. Farmers' engagement within their community through memberships of local groups, for instance, may mean the building of the social capital stock of shared values and norms – in cases where these include environmental values and the norms of sustainability related behaviours (e.g. waste reduction, recycling, choosing of environmentally friendly products) –

it may lead to flow-on effects that encourage farm-level practices that are in line with such values and norms.

1.6 Cultural Capital

Cultural capital is a community's embodied cultural skills and values, in all their community-defined forms, inherited from the community's previous generation, undergoing adaptation and extension by current members of the community, and desired by the community to be passed on to its next generation (Dalziel et al., 2009). 'The cultural context in which shared attitudes, values and knowledge are transmitted from generation to generation is important in understanding the choices of individuals and groups in relation to co-operation. Shared norms and values enable people to communicate and make sense of common experiences as well as divergences in some norms and values' (ibid., p. 41).

Another potentially problematic area is that although it is widely accepted that 'sustainable development requires maintenance of natural capital, the relationship between natural capital and other types of capital remains a matter of debate' (United Nations, et al., 2003, p. 5). While it may be generally agreed that all capital types are essential for the achievement of sustainability, views differ as to whether the various types of capital serve as substitutes for one another or if they are necessary complements to each other (ibid.). One contentious area of debate is 'whether natural capital can be replaced by other forms' (ibid., p. 6). Some argue that it is often possible to replace natural capital with human-made and human capital (ibid.). Some such examples include the use of human-made and human capital in the production of synthetic fertiliser, which replaces the natural soil fertility (ibid.). 'Even soil itself can be replaced in a limited way through the use of hydroponics' (ibid., p. 6). Such replaces have sometimes been inevitable; for instance, the building of sewage treatment plants as substitutes to natural waterways for waste disposal. 'Because sewage production far exceeds that which rivers could accept without suffering a dramatic decrease in functioning, society has been forced to divert financial and human resources away from other purposes into the production and operation of sewage treatment plants. These plants do nothing more than replace the waste assimilation service that the natural capital (the river) cannot provide at current levels of sewage production' (ibid., p. 5). 'History is full of similar examples where technological advancement has allowed substitution of scarce resources with those that are more abundant. Many would claim there is every reason to believe that such advancement will continue, even at increased rates, in the future' (ibid., p.6).

Another problem that is likely to be encountered in current attempts applying the *capital approach to sustainability* is that the five categories of capital are not 'equally well understood, either conceptually or empirically' (United Nations, 2008, p. 44). Financial capital is perhaps the best understood, followed by human-made capital, natural capital, human capital and social capital (ibid.). 'Social capital, the least well studied of the five, remains a controversial concept for which no single definition is universally accepted' (ibid., p. 44). 'Some forms of capital, particularly human and social, cannot be treated in complete analogy with financial or fixed capital. Human capital, it is noted, is what use to be called human potential or human resources, while social capital resembles the notion of social cohesion or social institutions' (ibid., p. 44). Therefore, the differences between the various categories of capital and the current lack of a clear definition and understanding of certain groups of capital is likely to pose a problem to the application of capital-based indicators of sustainability.

2 Agricultural Sustainability – A Need for Measurement

Historically, agricultural practices have had a particularly important role to play in the evolution of the concept of sustainability. The consequences of indiscriminate pesticide use in agriculture, as raised in Rachel Carson's *Silent Sprin*g stirred the earlier concerns about sustainability in the 1960s. Agriculture has since been a central concern in sustainability debates for two key reasons – one, its extensive use of natural resources which means a potential for widespread and extensive environmental effects, and two, the fact that its end product is food which makes it a foundation of human society (Bell and Morse, 2008). This makes agricultural sustainability highly critical, pointing to a need for viable tools of its measurement.

Within an agriculture system, van Calker et al., (2008, p.408) suggest that economic sustainability may be 'defined as the ability of the…farmer to continue his farming business (economic viability)'. They subdivide social sustainability to include the internal type which concerns 'qualitative and quantitative working conditions for the farm operator and employees' and the external type which relates to 'societal concern about the impact of agriculture on the well being of people and animals' (ibid., p.408). 'Ecological sustainability concerns threats or benefits to flora, fauna, soil, water and climate…' (ibid., p.408).

While there is likely to be varying views about what is required within the various components in ensuring sustainability within a given situation, when it concerns agriculture, in all cases there is a strong dependence on the availability of a range of different types of resources (van Loon et al., 2005). In fact, agricultural activities appear to rely on all five types of capital discussed above. As noted by van Loon et al., (2005, p. 48) these include:

- **Natural capital** – the soil resource, water from rainfall or other sources, the air, animals used for their labour and as a source of manure, the surrounding natural vegetation;
- **Human capital** – humans who supply labour, not only physical labour but also intellectual input for planning production strategies;
- **Social capital** – systems providing labour and marketing support as well as information related to agriculture and health services;
- **Financial capital** – markets for purchase and sale of goods, a credit system supplying funds to all levels of agricultural workers; and
- **Human-made capital** – implements needed for agriculture, roads and means of transport, factories for processing of farm produce.

At every level, an agricultural system depends 'on the value of services flowing from the total stock of' these five types of capital (Pretty, 2008, p. 451). As an economic sector, agriculture is one that is unique because of its capacity to directly affect 'many of the very assets on which it relies for success' (ibid., p. 451). In propagating sustainable agriculture, policy makers are keen 'to combine economic performance and a sustainable use of natural resources' (van Passel, 2007, p. 149). There is therefore a requirement that the practices of sustainable agriculture take into account each type of capital that it relies on (van Loon et al., 2005). While 'the various forms of capital are continuously being used' in food production operations, there is also a need for these operations to be 'sensitive to the need to *build up'* the various types of capital 'so that a balance is maintained' (ibid., p. 48). From a capital-based perspective, 'terms such as natural, social and human capital are useful in helping to shape concepts around basic questions such as what is agriculture for and what system works best' (Pretty, 2008, p. 452). Moreover, as noted by Statistics New Zealand (2002, p. 89), sustainable development initiatives often take on the capital approach which is 'based on the concept of maintaining [the] natural, economic and social base [of human society] over time' in order to provide future generations with 'the means and options to pursue their own goals.'

Since agricultural systems function in close connection with the natural environment, related assessment indicators would need to move beyond an assessment of their functions as if they were stocks of capital to have a strong sustainability element. Kemp et al., (2001) argue that indicators such as water efficiency, fertiliser inputs, soil chemistry and crop diversity, while useful for estimating and monitoring the production efficiency of a farm, may not necessarily relate to sustainability of the resource base over the long haul. They propose the necessity to perceive an agricultural system as if it were an ecosystem, since agriculture essentially functions within the wider natural ecosystem. This would mean a shift away from likening an agricultural system to a factory system where it would be possible to convert all resources into products. Instead, agriculture needs to be seen as a "purposeful human activity system" that reaps products from the ecosystem. To ensure the efficiency of this activity, it is essential that the wholeness, stability and balance of the ecosystem be preserved. For instance, natural processes such as nutrient cycling and the balance between pest and beneficial organisms need to be maintained for an agricultural system to be sustainable.

Thus, a key challenge for sustainable agriculture and the concept of sustainability in general lies in giving a greater emphasis in considering each type of capital when measuring progress towards sustainability. For these reasons, establishing a clearer understanding of each type of capital within an agricultural system appears critical. The establishment of such an understanding and the use of capital-based indicators in measuring sustainability not only has the potential to be an important measurement device that can prescribe ways for moving forward in making the concept of sustainability a viable goal, but it also has the potential to uplift sustainable agriculture as an appealing approach. For instance, positive correlations between farm level capital-based sustainability indicators and economic performance of farms are likely to be a motivating factor for farmers to adopt and retain the incorporation of indicator-based monitoring in farm practice and management. This acceptance in turn could aid the implementation and evaluation of established agri-environmental policies within a country, improve related decision-making, and facilitate the achievement of agricultural sustainability. Establishing and highlighting such relations would be of importance, considering the concerns over limitations in endurance of farmers' participation in voluntary agri-environmental schemes that Morris and Potter (1995) note and farmers' non-use of professionally established sustainability indicators as Carruthers and Tinning (2003) note. In a survey of farmers in New Zealand, Fairweather and Campbell (2002, p. 297) found that although most farmers were inclined towards 'at least a vague version of the agro-ecological approach to farming', their levels of commitment were variable. Although these farmers express an interest in the agro-ecological farming approach, the actual materialisation of related practices were somewhat limited (ibid.). In general, although the adoption of environmentally friendly farm management practices has seen rapid increase in New Zealand over the decades, general adoption rates remain low (OECD, 2008). As Pannell and Glenn (2000, p. 136) assert: 'In choosing indicators to recommend to farmers, it has to be recognised that whatever is recommended to them, farmers will make their own, independent choices based solely on their own perceptions about whether indicators are worth monitoring.' Therefore, it is essential to highlight that the approach taken in developing and recommending indicators highlights the 'worthiness' of those indicators.

In spite of the differences in the definitions of sustainability and the different approaches to its achievement, as van Passel et al*.,* (2007, p. 149) point out, 'there is a clear consensus to move from definition attempts toward developing and using concrete tools for measuring and promoting actual sustainability achievements'. This paper argues that capital-based sustainability indicators have the potential to be such a concrete measurement device for measuring agricultural sustainability.

2.1 Current Progress in the Development of Capital-based Indicators of Sustainability

The New Zealand government's "*Linked Indicators Project*" led by Statistics New Zealand has identified a set of core sustainable development indicators that encompasses the social, economic, environmental, and cultural elements of human wellbeing (See Statistics New Zealand, Analytical Reports, Linked Indicators http://www.stats.govt.nz/analytical-reports/default.htm). The selected indicators are detailed within four broad categories:

1. **Economic indicators** which provide measurements of income and socio-economic status which in turn measures people's wellbeing through their capability to buy goods and services, to acquire sufficient food and adequate housing and to take part within the wider community;
2. **Social indicators** which illustrate a society's attributes or characteristics and in connection to this indicator set, social well-being indicators comprise the aspects of human life that contribute to happiness, life quality and welfare as agreed upon by society in general;
3. **Environmental indicators** which consists of the built environment as well as aspects of the natural environment such as the quality of air, water, and biodiversity which can directly determine people's quality of life and thus their wellbeing; and
4. **Cultural indicators** such as 'the customs, practices, languages, values and world views that define social groups' which provide a measurement of cultural engagement, cultural identity, and heritage, which in turn provide a measurement of wellbeing since identification with a specific culture generates a feeling of belongingness and security. Cultural capital in particular has been identified to be 'an integral part of sustainable development for New Zealand' (Statistics New Zealand, 2002, p. 90) and has been the topic of a recent report (Dalziel et al., 2009).

Appendix 1 gives an extensive list of the possible different types of capital relevant for the agricultural sector. These different types of capital have been categorised and defined variably in the literature.

3 The ARGOS Programme and its Use of Capital-based Sustainability Indicators in the Evaluation of Agricultural Systems

From an overarching perspective the individual research programmes undertaken by the *Agricultural Research Group on Sustainability* (ARGOS)[1] may serve in providing a preliminary examination of the use of the various categories of capital indicators in evaluating the sustainability of farming systems.

ARGOS is undertaking a longitudinal study called '*Pathways to Sustainability*', which is determining the environmental, economic and social characteristics of primary production processes in New Zealand with the goal of assessing the sustainability and socio-ecological resilience of farming. A number of agricultural sectors are involved, including kiwifruit, sheep & beef (lowland and high country), dairy and farms owned by Ngai Tahu landowners. ARGOS is also assessing market developments overseas and how these are likely to affect and be implemented in New Zealand. The costs of implementation and potential benefits of these will be further assessed. This research has been funded by the Foundation for Research and Technology (FRST) and Industry, since 2003 and is ongoing.

For this piece of research, the kiwifruit and sheep and beef sectors have been investigated. Within the kiwifruit section of this work, 12 clusters of orchards are being studied, with each cluster containing one of each orchard type (Gold (EurepGap Certified Gold), Green (EurepGap Certified Green), Organic Green; 36 orchards in total). The orchards within each cluster are located close together to minimise differences in background factors like soil type and climate. Ten clusters are in the Bay of Plenty, with one each in Kerikeri and Motueka. These locations are consistent with the industry distribution of orchards and will potentially allow extrapolation to the wider industry.

In the sheep & beef section of this work there are again 12 clusters of farms being studied, with each cluster containing one certified organic, one farm that was involved in a quality-assurance audited supply chain (integrated) and one conventionally run farm. Unfortunately, by the end of the 2006/07 season, six of these farms had withdrawn from the study, primarily due to farm sales. One converting organic farm had been added. The properties within a cluster are within close geographic proximity with similar landforms, soil type and climatic conditions. The 12 clusters are located throughout the South Island from Marlborough to Southland.

Initial research has provided the opportunity to identify some of the previously discussed indicators, and to determine whether they are useful in characterising different forms of capital. While only a small number of farms were used within the current piece of work, it enables a brief look at the feasibility of using such measures, and the ability to identify any differences that exist between the different management systems used by farmers. Not all data collected is presented in this paper, rather a selection of different measures collected for the different types of capitals.

Data are presented for three of the five capitals of interest: human-made, social and natural capital. Results for both kiwifruit orchards and sheep and beef farms are presented.

[1] ARGOS is an unincorporated joint venture between the Agribusiness Group, Lincoln University, and the University of Otago. It is funded by the Foundation for Research, Science and Technology (FRST) and various industry stakeholders and commenced in October 2003. ARGOS has a mandate to examine the environmental, social and economic sustainability of New Zealand farming systems.

i. Human-Made Capital

Six years of data were available for the human capital analysis (2002/03 to 2007/08). An unbalanced ANOVA, with 'system' as treatment and 'season' as a blocking factor was run to determine whether the type of fruit grown on an orchard had any impact on the value of human-made capital. Two measures were available from the ARGOS database that measured human-made capital, namely 'Land & Buildings' (which was information collected from Quotable Value New Zealand (QV)) and 'Plant, Machinery & Vehicles' (which was an estimate provided by individual growers). A further two elements were analysed based on calculations undertaken, namely debt:equity ratio and stock units per hectare (for sheep and beef farms only). All calculations were carried out with data at a 'per hectare' level.

As Table 1 shows, there is a significant difference between fruit type grown for both measures identified for human-made capital for kiwifruit orchards. With respect to Land & Buildings, the QV of Gold orchards are significantly higher than that of Green and Organic orchards. There was no significant difference between Green and Organic orchards. Interestingly, season also showed a significant difference (F=0.002).

In relation to plant, machinery & vehicles, is a clear significant difference between orchard types is observed (F=0.039). However, for this measure, we see that Green orchards have plant, machinery and vehicles that are worth significantly more than Organic and Gold orchards. There is no significant difference between Organic and Gold orchards in the value of their plant, machinery and vehicles. Perhaps this is due to a need for less such capital required on a Gold orchard compared to a Green orchard. Being significantly lower in value does not necessarily mean that Gold orchards are less sustainable in this area. There was no significant difference between the debt:equity ratio for kiwifruit orchards.

Table 1. Means and significant difference between Green, Organic and Gold kiwifruit orchards for selected human-made capital measures

	Land & Buildings[2]	Plant, Machinery & Vehicles	Debt:Equity Ratio
Green	$352, 622	$39,311	0.15
Organic	$332, 250	$18,928	0.14
Gold	$436, 365	$8.050	0.11
Significant Difference	*	*	*ns*

*P<0.05, **P<0.001, ***P<0.0001

In running the same analysis for the sheep and beef farms, a significant difference is only observed for stock units per hectare (F=0.031) (Table 2). C and B farms both have a significantly higher number of stock units per hectare than do A farms. The value of the human-made capital is also notably lower than that observed for the kiwifruit orchards.

[2] Values are obtained from QV New Zealand

Table 2. Means and significant difference between A, B & C sheep and beef farms for selected human-made capital measures

	Land & Buildings[2]	Plant, Machinery & Vehicles	Debt:Equity Ratio	Stock Units per Hectare
A	$9, 178	$547	0.23	8.6
B	$9, 540	$499	0.39	9.9
C	$10, 180	$523	0.38	10.2
Significant Difference	*ns*	*ns*	*ns*	*

*P<0.05, **P<0.001, ***P<0.0001

ii. Social Capital

Only one year's worth of data was available for potential social capital indicators. While there were a number of different measures that could have been used to measure social capital, the four measures that were chosen in this piece of work were chosen as they have been used in other research identified in the literature. Therefore, the four measures used were: voting in national elections; voting in local elections; providing cash financial support to community activities; and agreement with the statement 'my orchard is contributing to the local community'. All questions were asked in respect to a 7-point scale, with one representing 'not at all involved', and seven representing 'heavily involved' (for the first three measures), and one representing 'very strongly disagree' and seven representing 'very strongly agree' for the final measure. An unbalanced ANOVA with management system as the treatment was run to determine if any significant differences existed between orchard types.

For both the kiwifruit orchards and the sheep and beef farms none of the measures showed any significant difference between management approaches (see Tables 3 and 4). However, what is more useful with measurements such as these are the changes over time that will have an impact on sustainability, rather than a one-off measurement (as there is no right or wrong level). Such measures should be constant, if not improving over time, and thus a simple one-off measurement such as this is not particularly useful at this early stage. Further research over time is required to see if the measures used in the present research are useful, and whether there are in fact changes over time, both at an orchard-type level and at a measurement level. Research is currently being undertaken to re-measure these indicators in upcoming years.

Table 3. Means and significant difference between Green, Organic and Gold kiwifruit orchards for selected social capital measures

	Voting in National Elections	Voting in Local Elections	Providing Cash Financial Support to Community Activities	Orchard is Contributing to the Local Community
Green	5.9	5.5	3.7	4.7
Organic	5.8	5.3	3.3	5.6
Gold	5.6	5.0	3.2	4.6
Significant Difference	*ns*	*ns*	*ns*	*ns*

Table 4. Means and significant difference between conventional, integrated and organic sheep & beef farms for selected social capital measures

	Voting in National Elections	Voting in Local Elections	Providing Cash Financial Support to Community Activities	Orchard is Contributing to the Local Community
Conventional	4.6	6.8	6.6	3.6
Integrated	3.6	5.9	6.0	3.4
Organic	4.8	5.4	5.4	4.2
Significant Difference	*ns*	*ns*	*ns*	*ns*

In running an analysis on a wider range of potential indicators, two elements emerge as close to significance for kiwifruit orchards: participation in school or education groups (F=0.071) and participation in church groups and/or care agencies (F=0.078). The same analysis on sheep and beef farms did not lead to any potentially useful indicators.

A national survey of Farmers and Orchardists within New Zealand is undertaken annually. This survey covers many of the same potential social indicators that were assessed for the ARGOS farms and orchards. From the national survey, the following significant differences were observed for measures that related to community participation for horticulture (approximately nine kiwifruit orchards) and sheep and beef farms (Fairweather et al, 2009):

Table 5. Means and significant difference between Conventional, Modified and Organic horticultural orchards for selected social capital measures – National Survey

	Voting in National Elections	Voting in Local Elections
Conventional	6.38^{a}	6.03^{a}
Modified	6.19^{a}	5.55
Organic	5.46^{b}	5.13^{b}

Table 6. Means and significant difference between conventional, integrated and organic sheep & beef farms for selected social capital measures – National Survey

	Contributing to the local community	Participation in school or education groups	Providing cash financial support to community activities
Conventional	4.02^{b}	2.91^{b}	3.72^{b}
Integrated	5.16^{a}	3.41	5.11^{a}
Organic	4.85^{a}	3.85^{a}	3.95^{b}

iii. Natural Capital

Carey et al., (2009) have recently published results on the measurement of natural capital, using the ARGOS data for kiwifruit orchards. To reduce duplication, the present paper is presenting selected elements of the data presented by Carey et al., to illustrate the measurement of natural capital. Those measures presented here are: Soluble C; Microbial biomass N; Olsen P; pH; and the number of earthworms. Again, an ANOVA was run to determine the differences between orchard type (for full details of the analysis conducted, see Carey et al., 2009). Measurements were taken both between rows and within rows for the different management systems and analysed. For the purposes of this paper only the results relevant to the management system are presented.

The same analysis for the sheep and beef farms was not possible due to the non-orthogonal nature of the data. Thus, an unbalanced ANOVA was conducted, with management type as the treatment structure and year and landform (where the measurement was taken from) set as blocking factors. Only two years of data were available to run this analysis. Due to the unbalanced nature of the data, it was not possible for landform to be included in the analysis as a variable.

A range of results were observed for the measurement of natural capital for kiwifruit (see Table 7). No significant difference was observed between orchard types for Soluble C. Microbial biomass N was greater for Organic orchards than either Green or Gold orchards. Olsen P was significantly lower for Organic orchards than Gold orchards, with no difference between Green orchards and any other orchard type observed. Soil pH was significantly higher for Organic orchards than Green and Gold orchards, although these differences were small. Finally, there were significantly more earthworms in Organic orchards than Green or Gold orchards.

Although differences are described above, there is no consistency amongst these differences, although Organic orchards were observed to be higher in microbial mass N, pH and number of earthworms.

Table 7. Means and significant difference between Green, Organic and Gold kiwifruit orchards for selected natural capital measures

	Sampling Position	**Soluble C** ***(mg C kg^{-1})***	**Microbial biomass – N** ***(mg N kg^{-1})***	**Olsen P** ***(mg P kg^{-1} soil)***	**pH**	**Earthworms** ***(No. m^{-2})***
Green	WR[3]	133	53	55.5	6.5	51
	BR[4]	144	76	40.8	6.5	106
Organic	WR	143	88	50.3	6.6	119
	BR	148	99	37.1	6.8	149
Gold	WR	151	64	65.6	6.2	61
	BR	157	86	50.0	6.5	87
Significant Difference		*ns*	***	*	***	*

From: Carey et al., 2009
*P<0.05, **P<0.001, ***P<0.0001

Minimal differences were observed for the sheep and beef farms for the selected measures of natural capital (Table 8). Olsen P was the only measure that shows a significant difference between management type (F=<0.001). Both integrated and conventional farms have a significantly higher level of Olsen P than organic farms.

[3] Measurement taken within row
[4] Measurement taken between row

Table 8. Means and significant difference between conventional, integrated and organic sheep & beef farms for selected natural capital measures

	Soluble C *(mg C kg^{-1})*	**Microbial biomass – N** *(mg N kg^{-1})*	**Olsen P** *(mg P kg^{-1} soil)*	**pH**	**Earthworms** *(No. m^{-2})*
Organic	131	33	13	5.9	409
Integrated	129	35	25	5.9	399
Conventional	132	35	24	5.8	431
Significant Difference	*ns*	*ns*	**	*ns*	*ns*

*P<0.05, **P<0.001, ***P<0.0001

Further analysis was undertaken assessing the number of cicadas on kiwifruit orchards. When analysed, it was found that there was a significant difference between orchard type for cicada numbers (F=<0.001). Green orchards had significantly more cicadas than both Gold and Organic orchards. Organic orchards have significantly more cicadas than Gold orchards. When looked at over time, there is also a significant difference between years (F=<0.001), but not between the year and system interaction (F=0.348).

4 Conclusion

Although the above results do show a number of significant differences for different measures of capital, what is important to note that many of these measures have no right or wrong level as to what is acceptable. What is more important are the changes that are occurring over time. For most measures, remaining consistent or increasing over time is more important than level itself. For example, for many of the social capital measures, the level of, say, voting participation should remain the same over time, if not increase to show how involvement in the local community is increasing (or remaining constant). Having said that, there are some measures that need to remain constant or decrease, e.g., greenhouse emissions. Similarly, many of the natural capital measurements are likely to have an ‘ideal’ range at which they should fall between (to ensure that deterioration is not occurring to the natural environment).

This paper has allowed a brief discussion of some of the potential measures of capital (particularly human-made, social and natural) to be discussed and using data available from the ARGOS work currently being undertaken, measurements are provided for a number of potential indicators. This work provides a platform for further research and also allows for future studies to be undertaken allowing for the comparison across years for some of these measures to build a bigger picture of how capital is changing over time.

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Appendix 1
Categorisation of Capital within the Agriculture Sector

Indicator Terminology and Source	Indicator Categories
Performance Indicators for Agribusiness *(Saunders et al., 2007)*	***Human Capital*** • Employment (full- time, part-time, unemployed) • Qualifications of employees • Skill level and experience of employees • Attributes of employees ***Human-Made Capital*** • Buildings by type and age • Water (water races and potable supplies) • Power distribution (network capacity and current delivery) • Telecommunications (access to phone, internet and fax; and data capacity) ***Natural Capital*** • Land use (by type) • Water quality • Green house gas emissions • Energy use • Water (stockwater, groundwater riparian water usage) • Soil fertility • Climate ***Social Capital*** • Turnout at elections • Membership of local groups • Donations to local groups • Use of local facilities (e.g., Doctor) ***Cultural Capital*** • Ethnic group • Usage rates of public halls and recreation centres • Length of time in locality
Statistics New Zealand, Analytical Reports, Linked Indicators *(Statistics New Zealand, 2002)*	***Environmental Indicators*** • Look and feel of the city • Traffic and transport • National environmental air quality standards • Greenhouse gasses • Indigenous vegetation • Native birds • Contaminated sites • Land cover and use • Energy use • National water quality • National water quantity (surface and groundwater) ***Economic Indicators*** • Tourism – number of guest nights purchased • Building – building consents • Migration flows • Openness to trade • Income

	• Social deprivation • Share of national economy • Household consumption • Unemployment • Employment • Real capital investment • Infrastructure (quality) • Research and development (financing) • Intangible investment ***Social Indicators*** • Voting at general elections • Life expectancy • Injury rates • Household size • Number of households • Participation in sport and active leisure • Criminal victimisation • Perceptions of safety • Road causalities • Educational attainment • Early childhood education • Quality of life • Telephone and internet access at home ***Cultural Indicators*** • Language retention • Maori language speakers • Employment in cultural industry • Local content on New Zealand television • Historic places
Agricultural Capital *(Table 1.1. Strategies for building up various forms of capital required for agricultural food production) (Pretty, 1999 cited in van Loon et al., 2005, p.48)*	***Natural Capital*** • Water harvesting, water management • Soil conservation • Biological pest control • Composting, manuring • Diverse systems • Conserving genetic resources ***Social Capital*** • Co-operatives • Extension workers: Government, NGO, private • Farmers self-help and research activities • Social values and systems ***Human Capital*** • Improved nutrition • Education • Health ***Financial Capital*** • Stable markets • Subsidiary activities • Readily available credit • Post-harvest technological opportunities • Value-added activities ***Physical Capital*** • Improved tools, machinery • Precision agriculture methods • Low dose sprays

	• Improved crop varieties • Roads • Processing plant
Sustainability Indicators *(Bond and Klonsky, 2006)*	***Input Based Sustainability Indicators*** ***Man-made and Human Capital Indicators*** • Pesticide Use • Fertiliser Use • Labour Use • Machinery Use • Livestock Use ***Natural Capital Indicators*** *Soil* • Soil physical, chemical and biological properties • Soil erosion • Fertiliser use • Use of Tillage Practices • Use of hedgerows and walls • Use of alternative cropping systems (rotation, intercropping, etc.) *Land* • Area of deforestation • Categories of land use • Inherent land quality (slope, altitude, etc.) *Water* • Water use • Depth of groundwater table • Water storage capacity • Concentrations of pollutants in ground and surface water • Water salinity *Energy* • Categories of energy use ***Institutional and Economic Sustainability Indicators*** ***Social Capital and Institutions*** • Access to land, water, markets, and credits • Quality of life measures • Provision of services (healthcare, education, etc.) • Land Tenure • Market Characteristics (especially prices) ***Risk*** • Yield variability • Probability of system failure • Use of risk-reducing management practices • Input self-sufficiency • Biodiversity ***Revenues, Costs, and Employment*** • Farm profits (revenues less costs) • NPV of returns • Farm assets • Leverage ratios • Regional/national income • Agricultural employment • Subsidies/environment payments • Credit Availability ***Output Based Sustainability Indicators***

	Output and Production *Good* • Crop/tree/animal yield • Production per capita • Technology • Output/input ratio • Total factor productivity • Total social factor productivity *Bad (Externalities)* • Air pollution (concentrations and emissions) • Water pollution (concentrations and emissions, leaching and runoff) • Food pollution (related to pesticides) • Land pollution (acidification, etc.) • Soil erosion • Nutrient losses/balances • Biodiversity measures/depletion • Habitat destruction • Land Use • Pesticide Use • Fertiliser Use • Other management practices
Sustainability indicators and attributes of agricultural sustainability *(SCARM, 1993)*	***Economic Indicators*** *Real Net Farm Income* • Net farm income • Productivity terms of trade • Area of land used for agriculture

	Off-Site Environmental Impacts • Food chemical contamination level • River turbidity • Dust storm frequency • Length of contact zones *Land and Water Quality* • Water use efficiency • Nutrient balance • Area of native vegetation • Degree of vegetation fragmentation ***Social Indicators*** • Managerial skill of farmers, landowners and land managers in finance, farming practice and environmental stewardship – e.g. decision making about the products grown, physical farm management including operational planning and conservation, financial planning, and the capacity to realise personal and societal goals • Formal knowledge – educational level of those employed in farming compared to that of the rest of the community (full school education/higher education) • Skills base – e.g. literacy, numeracy, driving, welding, machinery operation and computing (while farming skills are taught in rural education institutions, many farmers have acquired skills through years of experience and there is a danger of undervaluing this) • Attitudes of the land managers – ethics, codes of practice, and organisational memberships (e.g. membership within conservation groups or other community land management groups, such as Landcare), public awareness of conservation, the proportion of community attending training courses and the degree of promotion of conservation practices by advisory services, the proportion of farmers using multiple sources of information such as advisory services and consultants • Planning capacity of farmers – farm planning (e.g. use of physical and financial plans), responses to risk and financial management
Sustainability Indicators *(Smyth and Dumanski, 1993)*	***Economic Indicators*** • Profitability ***Biophysical Indicators*** • Off-site biophysical indicators. The most frequently cited off-site environmental impacts arising from both historical and present agricultural activities include: • The alteration of landscape hydrology by clearance of deep rooted perennial vegetation; • Rise in ground water through the excessive use of irrigation waters; • Siltation of rivers, dams, and natural water bodies, and atmospheric pollution, through

	surface soil transportation by water and wind; • Leaching of fertilisers and pesticides into ground waters and streams, and aerial pesticide pollution leading to human health problems, through inappropriate use of agricultural chemicals; and • Loss of natural flora and fauna through large-scale clearing of native habitats
Indicators for Sustainable Development *(Bossel, 1999)*	***Human Capital*** • Human system = social system + individual development + government • Individual potential describes the potential for competent individual action as produced by – and producing – the possibilities for individual development. It is the accumulated result of tradition and culture as well as socio-political and economic conditions • Social potential denotes something less tangible: the ability to deal constructively with social processes, and to employ them for the benefit of the total system. This has a strong cultural component determining social coherence and relationships. It includes such aspects as honesty, trust, competence and efficiency • Organisational potential, as manifest in the know-how and performance standards of government, administration, business and management, is vital for effective resource use (natural and human) for the benefit of the total system ***Structural (built) Capital*** • Support system = infrastructure + economic system • Infrastructure potential denotes the stock of built structures like cities, roads, water supply systems, schools and universities. It is the essential backbone of all economic and social activity • Production potential of the economic system includes the stock of production, distribution and marketing facilities. It provides the means for all economic activity ***Natural Capital*** • Natural system = resources + environment • Natural potential represents the stock of renewable and non-renewable resources of materials, energy and biosystems, including the capacity for waste absorption and regeneration
Indicators for the Economic and Social Dimensions of Sustainable Agriculture and Rural Development *(European Commission, 2001)*	***Economic Dimension*** *Efficiency Indicators* • Output (quality and quantity) • Competitiveness and viability indicators *Over Space* • Viability of rural communities and the maintenance of a balanced pattern of development including the agricultural sector's contribution ***Social Dimension*** *Efficiency Indicators*

	• Employment • Institutional efficiency *Over Space/Sectors* • Access to resources/services and opportunities *Social Groups* • Equal opportunities *Ethics* • Labour conditions • Animal welfare