Targets for sustainable and resilient agriculture (TSARA): A New Zealand perspective

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Contents

1. EXECUTIVE SUMMARY

Targets for sustainable and resilient agriculture (**TSARA**) is a European research programme that is investigating land uses and changes to land uses, their potential to support progress toward the United Nations (**UN**) Sustainable Development Goals (**SDG**) and pathways from the current situation to defined future end states. To analyse these pathways, TSARA will use a complex land-use model developed by Rothamsted Research in the United Kingdom (UK). AgResearch is participating in the TSARA programme by using New Zealand as a non-European case study for additional modelling.

This report represents the first phase of AgResearch's collaboration in TSARA. It describes the data required to parameterise the existing Rothamsted Research/TSARA model for New Zealand conditions, and evaluates the feasibility of providing sufficient data to model New Zealand pathways successfully. There are three groups of data required for the research. The first group of data includes farming activities and land uses. Drawing on several sources of data, we identified sufficient data on the different types of land uses in New Zealand to provide data for the TSARA model. Given the importance of pastoral agriculture in the country, a large fraction of the data concerns sheep and beef systems and dairy systems. The second group of data describes the natural resources of New Zealand according to a number of agri-environmental zones (**AEZ**). While the AEZ, and the criteria for distinguishing them, are different from the European typology, there is sufficient commonality in the approach to populate the TSARA model with data. The third group of data contains suggested indicators to track progress towards the SDG, in particular SDG 2 regarding food production and security. Based on work with stakeholders, we have identified several useful and feasible indicators that can be linked to land uses.

This preliminary work has identified variables and data sets that can be used to populate the TSARA model in order to investigate pathways to achieving SDG in New Zealand. The next step will be to collaborate with European TSARA researchers to modify the model for New Zealand and begin to model these pathways.

2. INTRODUCTION

2.1 Agriculture and SDG

With a growing global population coexisting with a limited set of natural resources, sustainable intensification of agriculture on current agricultural land is becoming a crucial challenge. With additional pressures such as climate change, preservation of natural ecosystems and the need to grow food, fibre and fuel, pressure on agricultural production systems is vast and swelling, often with international literature in agreement that the global agriculture and food system in its current form is not sustainable (Wadsworth et al., 2003; Buckwell and Armstrong-Brown, 2004). Modern intensive farming, livestock farming in particular, is highly dependent on fossil fuels, and leads to environmental problems such as water pollution, soil degradation and greenhouse gas (**GHG**) emissions. Agricultural systems are continuously evolving and are forced to change as a result of a range of global and domestic driving forces. Agricultural technologies, as well as agricultural, environmental and rural development policies are increasingly being designed to contribute to the sustainability of agricultural systems and to enhance contributions of agricultural systems to sustainable development at large (van Ittersum et al., 2008).

Agriculture continues to be a major provider of goods, jobs and environmental services. Major shifts at international, national and sub-national scales, and in all sectors, from food production to consumption, are essential to improve the situation and achieve the new set of UN Sustainable Development Goals related to poverty, food and nutrition security, access to energy, health, rural development and the environment (Griggs et al., 2013). The SDG replace the Millennium Goals for the period 2015-2030. In September 2015, countries adopted a set of goals to end poverty, protect the planet, and ensure prosperity for all as part of a new sustainable development agenda (UN - Sustainable Development Goals, 2015). Many of the SDG relate specifically to agriculture and its use of resources (Dobermann and Nelson, 2013), the most prominent one being *SDG 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture*."

The goals, sometimes referred to as the post-2015 agenda, express an ambitious commitment and are specified as targets and indicators. Each goal has specific targets to be achieved over the next 15 years. While the SDG are not legally binding, governments are expected to take ownership and establish national frameworks for the achievement of the 17 Goals. Countries have the prime responsibility of developing and reviewing the progress made in implementing the Goals, which will require quality, accessible and timely data collection. In an iterative fashion, regional follow-up and review will be based on national-level analyses and contribute to follow-up and review at the global level.

2.2 TSARA Programme

Targets for sustainable and resilient agriculture (**TSARA**) is exploring means to support and develop pathways toward delivering to the SDG and their targets. TSARA is a three-year research programme funded through the Joint Programming Initiative on Agriculture, Food Security and Climate Change (**FACCE-JPI**). FACCE-JPI aggregates data from 22 countries that are committed to building an integrated European Research Area addressing the interconnected challenges of sustainable agriculture, food security and impacts of climate change. TSARA consists of a series of scientific and management work packages (**WP**), as follows:

- WP 1 (*typology of agricultural systems*) classifies EU agricultural land use and management into major types.
- WP 2 (*development of indicators*) suggests levels of delivery to SDG and their associated targets and indicators (e.g. a 30 per cent reduction in GHG emissions).
- WP 3 (*modelling and data for models and baselines*) investigates and develops models and collects the baseline data needed to run those models in order to forecast the outputs and wider impacts of agriculture over the next 15 years (for the SDG) and up to 2050 for FACCE-JPI. WP 3 also sets up the key operational framework for use in TSARA, a series of tables known as dashboards that record the changes in indicators of sustainable agriculture in the EU needed to achieve the desired targets for SDG by 2030. The approach is known as backcasting and consists of setting out the expected or desired state of agriculture in 2030 and then taking backward steps to see what the conditions are or would have to be in 2025, 2020 and 2015 to achieve this state.

- Having set up the current (baseline) and desired states of EU agriculture in WP 3, WP 4 (*backcasting and transformation pathways*) runs these analyses, populating the tables with a number of routes through the intermediate years to the targets. In this way, the team develops a range of alternative pathways to provide options in support of the pursuit of ambitious levels of national and transnational delivery in policy to the SDG and targets. WP 4 also investigates trade-offs between the delivery to different goals as well as social and political impediments along the way. TSARA thus iterates pathways to goals and targets as well as helping with the setting of ambitious levels of delivery to those targets.
- WP 5 (*stakeholder engagement*) engages with stakeholders to understand their concerns and reservations about pathways and targets so as to ensure buy-in at all levels of society with the eventual project outputs, which will be a series of strategies to deliver challenging improvements in the sustainability of EU agricultural practice.
- WP 6 (*management*) manages the project and liaises with the wider United Nations Sustainable Development Solutions Network (**SDSN**).

Briefly, Rothamsted Research (http://www.rothamsted.ac.uk/) coordinates the TSARA project (WP 6) and leads WP 3 focused on data and modelling, using a model from earlier research to model new data (Glendining et al., 2009). Wageningen University (http://www.wur.nl/en/wageningen-university.htm) provides data and systems analysis of agricultural and bioenergy systems at the farm scale and leads WP 1 and 2 on developing farm typologies and indicators (van Ittersum et al., 2008). The *Institut du Développement Durable et des Relations Internationales* (**IDDRI**; France) analyses the technical, economic, sociological and political drivers of transition pathways towards sustainability in bioenergy and agriculture. IDDRI leads WP 4 on backcasting and transformation pathways. The project aims to promote a strong participatory approach and to ensure the inclusion of a wide range of stakeholders in the building of transformation pathways aimed at achieving the SDG. The incorporation of IDDRI within the project brings a strong social science dimension to the elaboration of sustainable agricultural goals (http://blog.iddri.org/en/2016/07/05/transformation-pathways/).

In addition to the detailed studies in the three key EU nations in TSARA – UK, France and the Netherlands – the project has incorporated New Zealand as a contributor in adopting a similar backcasting approach to the delivery of the SDG. New Zealand intends to contribute to the achievement of the SDG through a combination of domestic action, international leadership on global policy issues, and supporting countries through the New Zealand Aid Programme (NZFA&T, 2017). AgResearch is the New Zealand research partner in TSARA. The inclusion of New Zealand is intended to provide a non-European case study for the modelling and analysis. The expectation is that including a non-European example will allow TSARA to assess a greater range of variables, because the agriculture, the environment and the SDG targets are all likely to be dependent on the specific country context. Because the original modelling that serves as a basis for TSARA was done in a European context, the first step in AgResearch's contribution was to assess the availability and suitability of data that could populate the model. This initial work feeds into WP 1 and WP 2. The next steps will focus on the later WPs, in particular the inclusion of New Zealand data in the TSARA model and the modelling of pathways to achieving the SDG.

2.3 Objective of the Report

This report presents the first stage in AgResearch's contribution to the TSARA research. It is a review of the data required for the TSARA modelling and the feasibility of populating the model with New Zealand data. The first objective of this report is to assess the feasibility of adding New Zealand's geospatial and biophysical data on farm typologies and agri-environmental zones (**AEZ**) to the larger TSARA programme. Stepwise, the four areas/topics to be covered are:

1. A farm typology of New Zealand (including land use description, distribution, scale, farming intensity).
2. Spatial tools used to locate farm typologies (AgriBase™, Land Cover Data Base; **LCDB**).
3. Attributes of AEZ and of a spatial agri-environmental framework.
4. Description of AEZ in New Zealand.
5. Predominant farm typologies within each AEZ and sources of information (e.g. Land Environments of New Zealand; **LENZ**).

The second objective of the report is to investigate the potential indicators that could be used to track progress on SDG. In particular, the concern is with identifying indicators that fulfil three requirements:

1. Stakeholders in agriculture find them meaningful and are willing to engage with them
2. The indicators are meaningful in the context of the SDG targets
3. They are feasible for the TSARA programme: data are potentially available and can be used in the modelling work.

The remainder of the report is organised as follows. The next section focuses specifically on the TSARA model and its data requirements for farm types and AEZ. The subsequent section reports on SDG in the New Zealand context, and reports on the results of stakeholder engagement to identify key metrics for assessing progress on SDG. A discussion section then considers the feasibility of including New Zealand in the analytical work of TSARA, and the report closes with a summary section.

3. MODELLING

3.1 TSARA approach

3.1.1 Details of the model

An overview of farming activities in the UK, France, and the Netherlands has led the pathway on the farm typologies that are currently being considered in the modelling simulations of the TSARA project (Andersen, 2017). The introductory step of the analyses in Andersen (2017) was to compile the information on the different agricultural sectors that are active on the landscape using recent advances in science, linking statistical data on agriculture to the biophysical component. The quantitative approach used statistics on farms and farm characteristics from the Farm Accountancy Data Network (**FADN**) (European Commission, 2015) to identify and describe the agricultural landscapes of the EU. The FADN is a European system of sample surveys conducted every year to collect accountancy data from farms, with the aim of monitoring the income and business activities of EU agricultural holdings. Moreover, the FADN is an important knowledge base for understanding the impact of the measures taken under the Common Agricultural Policy (**CAP**) on different types of agricultural holdings (European Commission, 2015). In this context, an agricultural landscape is conceptually understood as a distinct pattern of farming systems and landscape elements in a homogeneous biophysical and administrative capacity (Andersen et al., 2007). The concept can be expressed in a quantitative fashion, according to the following equation:

An agricultural landscape = $\int (C_{(t)}, R_{(t)}, S_{(t)}, FS_{(t)}, STR_{(t)})$

where C is climate, R is the administrative region, S is soils, FS are farming systems, STR are landscape elements and (t) is time (Andersen, 2017). The data used as input for the analyses originate from the integrated project System for Environmental and Agricultural Modelling – Linking Science and Society (**SEAMLESS**) (Janssen and van Ittersum, 2007). The SEAMLESS data offer a spatial framework developed to delineate spatial units with somewhat homogeneous conditions for farming in terms of climate, soil and administrative capacity, also defined as agri-environmental zones or zonation (**AEZ**) (Hazeu et al., 2010).

The SEAMLESS data include typologies of European agriculture based on FADN data that includes three dimensions: a) the *scale* of production, b) the *intensity* of farming, and c) the *specialisation* and *land use* (Andersen et al., 2007). Data on farm typologies features the share of each country's utilized agricultural area (**UAA**) per size (predominance of small, medium or large farm holdings), intensity (three levels of economic output per hectare, expressed as net revenue per ha), specialization and land use classes. The latter two cover similar aspects of the farm typology, with land use used in a more aggregated fashion than specialisation.

3.1.2 Data needs – farm typology and AEZ

The agri-environmental stratification in the TSARA Project provides a sampling basis of the wide variation of EU farming activity combinations in their condition to produce goods and services, and how these combinations respond to EU policies (van Ittersum et al., 2008). Integrated databases in SEAMLESS provide for a European-wide assessment of farming activities including biophysical variables such as soils, climate, topography, farm management, livestock and crops, a number of socio-economic aspects such as prices, income and employment, production data and trade flows, and policies at different levels (regional, national and international) (van Ittersum et al., 2008).

The rationale underlining the EU farm typologies is to classify farm holdings according to their main source of income. Farm typologies refer to a stratification of farming activities that are homogenous in a specific criteria relevant to policy, such as management practices and biophysical and environmental performance (Andersen et al., 2007). Stepwise, economic considerations triggered by agricultural policy changes drive changes in farm management, which in turn have environmental implications. As mentioned above, FADN is an important source of information, along with European soil maps and climate data from the Monitoring Agriculture with Remote Sensing (**MARS**) database, amongst others. A major advantage of using FADN is that it includes information on the *intensity* of farming, which cannot be found in other EU-wide datasets. Therefore, farm typologies are based on the combination of two dimensions, a land use (e.g. mixed crops) and an intensity dimension (e.g. *net value of an agricultural product on a per hectare basis*).

Building typologies of farms, rather than single farm data, has been the chosen pathway to distribute information amongst users (Janssen et al., 2011). Within TSARA, the creation of farm typologies assists in simplifying the vast amount of information on farming environments, conditions and systems (i.e. geospatial, biophysical, financial) into coherent groups that share similar characteristics. Typologies have been developed for a) farming systems based on farm size, intensity and a measure of specialisation/land use (Andersen et al., 2007), b) agri-environments, based on a combination of environmental zones (driven at large by climate), soil quality (i.e. organic carbon in topsoil) and suitability for agriculture (Hazeu et al., 2010), and c) the development of socio-economic regions based on population data such as population density, income and employment.

In addition, typologies also assist in the sampling of data or regions considered in a specific study; bio-economic farm models often require a considerable amount of data that is not consistently available throughout all regions in the EU. As a consequence, a number of sample regions have been identified as representative of different types of biophysical conditions and farm typologies diversity across the EU. These (more developed) typologies are currently being used to provide a spatial context for the assessment of indicators. In turn, the assessment of indicators can account for the heterogeneity in biophysical, economic and social conditions across the EU. This approach can be used to identify critical source areas, areas where changes in specific indicators are matched with specific vulnerabilities to these changes (e.g. an increase in livestock numbers in an area that is particularly sensitive to nitrogen leaching losses) (van Ittersum et al., 2008).

Overall, the selection of input data for the EU-AEZ is based on data availability, user-defined requirements, and experience from previous projects. The EU-AEZ are fundamentally based on four databases; the *Environmental Stratification of Europe (**EnS**),* the *European Soil Database (**ESDB**),* the *TOPsoil Organic Carbon (**OCTOP**)* and the *Global Digital Elevation Model (**GTOPO30**)* (Hazeu et al., 2010). The selection of these databases allows for a suitable stratification of ecological resources, the selection of sites for representative studies across the EU and for the provision of strata for modelling exercises and reporting at a European scale (Metzger et al., 2005).

Briefly, the EnS database, built on climatic variables, partitions environmental variation across a continental gradient. It doesn't acknowledge, however, regional variations in soil properties, which are critical to agronomic performance and environmental outcomes (Hazeu et al., 2010). The ESDB consists of a number of databases including geographical and pedotransfer rules databases, which contribute with a number of soil variables that are agronomically relevant in explaining variation in soil properties. The OCTOP database combines pedotransfer rules with spatial data layers to estimate soil organic carbon (**SOC**) contents across a variety of land uses (Jones et al., 2005). GTOPO30 is a global digital elevation model (**DEM**) covering the full extent of the territory, with ocean areas masked as 'no data' (Hazeu et al., 2010). From an agronomic perspective, the resultant AEZ consist of relatively homogenous spatial land units.

3.2 NZ Approach

3.2.1 Diversity and intensification of New Zealand agriculture

Land area in New Zealand is predominantly in forests and agriculture; roughly evenly split between the two, which occupy about 40% each (OECD, 2017). Over 75% of New Zealand's land mass is greater than 200 m above sea level, and unrelenting mountain building from movement of the underlying tectonic plates has resulted in a landscape dissected by fast flowing rivers and streams. New Zealand's agricultural industry has had a large and defining effect on the economy, on the environment, and on perceptions of national identity. In addition to the economic benefits of tourism, the natural environment provides the basis for New Zealand's large exports of dairy, meat, wool, fruit, vegetables, fish and wood. Total agricultural exports and those of pastoral origin accounted for about 60% and 47% of New Zealand's total exports in 2015. Of the total pastoral exports, about 61% and 34% corresponded to the dairy and meat and fibre sectors, respectively (Beef and Lamb New Zealand, 2016). New Zealand is the world's 12th largest agricultural exporter by value; it is the world's largest sheep meat and dairy product exporter, as well as the second largest wool and soft wood log exporter (MPI, 2017)

New Zealand farmers have achieved major productivity gains over the last two decades. Their exposure to the world markets and intense competition from producers located elsewhere has placed enormous pressure on them to farm more intensively (PCE, 2004, 2015). These pressures are visible and ongoing in agricultural, temperate-type commodity systems, in which products grown domestically are hard to differentiate from products grown elsewhere. Commodity producers face ongoing demands to farm more intensively in response to increasing costs of production and cost/price pressures, including rising costs of land and water and volatility of international commodity prices that undermine the profitability of their businesses. Evidence of acceleration in intensification, and to some extent diversification of the major land-based activities, has been shown for the previous decade (1997 – 2007). However, the drivers of these changes were deemed poorly understood, and their impacts on biodiversity conservation in farmed landscapes could not be distinguished from national indicators monitored at the time (MacLeod and Moller, 2006). Given that the New Zealand government seeks to dramatically increase the value of agricultural exports, even while simultaneously protecting the natural environment (MBIE, 2015), the process of agricultural intensification is likely to continue.

New Zealand has an open economy which is focused on the production of high quality agricultural products at low cost. Deregulation of the agricultural sector in the mid-1980s led to the removal of all farm subsidies (PCE, 2004). This created many financial difficulties for farmers who had become reliant on government involvement to protect their incomes. The deregulation was prompted to encourage more efficient use of resources in the needed drive to produce products which were competitive on global markets (Dalziel and Lattimore, 2004). Since the 1990s, agriculture has been largely driven by market demand; farmers have become more flexible to market and economic signals, and are more prone to land use change to adapt to these signals, than in the past (Moot et al., 2009). As a recent example of this responsiveness, the greater profitability of dairy relative to sheep and beef farming has prompted a large number of dairy conversions to occur over the last two decades (New Zealand Dairy Statistics, 2016).

3.2.2 Farm Types

a) Definition and Tools for Geospatial Assessment

Stemming from the notion that the farm is the baseline land unit at which decisions are made in terms of land management and natural resource use, farm typologies offer a tool for summarising the assessment of farm management indicators. Farm typologies, therefore, become the building block to assess farm management indicators within an agricultural policy context. A farm typology has been defined as a stratification of farms that exhibit some degree of homogeneity in terms of farm management practices and environmental performance (Andersen et al., 2007), and several factors come into play when aggregating farms to create such typologies. Rather than single measures, a farm typology offers a tool to assess farm management metrics (i.e. indicators) as an integrated set, emphasising linkages between the different indicators and allowing for a better understanding of the underlying drivers behind farm management decision-making.

Farm types in New Zealand were defined on similar variables to those used in the EU based TSARA project as described in **Table 1** below.

Table 1. Farm type variables in TSARA-EU and TSARA-NZ.

EU-TSARA criteria for farm types	New Zealand criteria for farm types
Specialization	Specialization
Intensity/Revenue	Land-use
Land-use	Geography
Size	

Intensity and size were not determinative of different farm types in New Zealand, but data on both variables (by farm type) is available in the New Zealand context.

A spatial and demographic census of New Zealand farms (AgriBase™; AsureQuality; herein AgriBase) provided major land uses and farm typology distribution throughout the country (AsureQuality, 2017) (***Figure 1***). The national spatial farms database was launched in 1993 (Sanson, 2005). It currently holds information on approximately 130,000 New Zealand farms (Michelle Barnes, AsureQuality, personal communication). Each farm is given a unique AgriBase identifier, next to which production data, geospatial polygons representing land parcels and property information based on farm type, are reported. AgriBase is a voluntary system that includes data on predominant farm type, size, animal numbers by stock class, areas for a variety of annual and perennial crops and orchard types (including forestry and vineyards), in addition to the spatial coordinates of the farm within a geographic information system (**GIS**). Industry sector groups use AgriBase as an index for all rural land holdings involved in primary production. It has been primarily used as a quantitative assessor of biosecurity issues; more specifically, it has been used in exotic disease and pest examinations and responses, in the development and delivery of food safety traceability and verification systems, and in the development of environmental indicators (Sanson, 2000; Sanson and Scott, 2003; Sanson, 2004, 2005).

A recent comparison of three New Zealand-wide livestock biosecurity databases [AgriBase, FarmsOnLine (**FOL**) and the National Animal Identification and Tracing Scheme (**NAIT**)] (Jewell et al., 2016) showed that the three databases were in broad agreement, but significant differences existed in both species composition and spatial coverage, which raises concerns over their accuracy. It was suggested that these databases cannot be reliably linked to provide a single picture of New Zealand's livestock sector; the authors also recommended that a single integrated database needs to be developed, for an efficient use of resources and legislation for continual updating (Jewell et al., 2016).

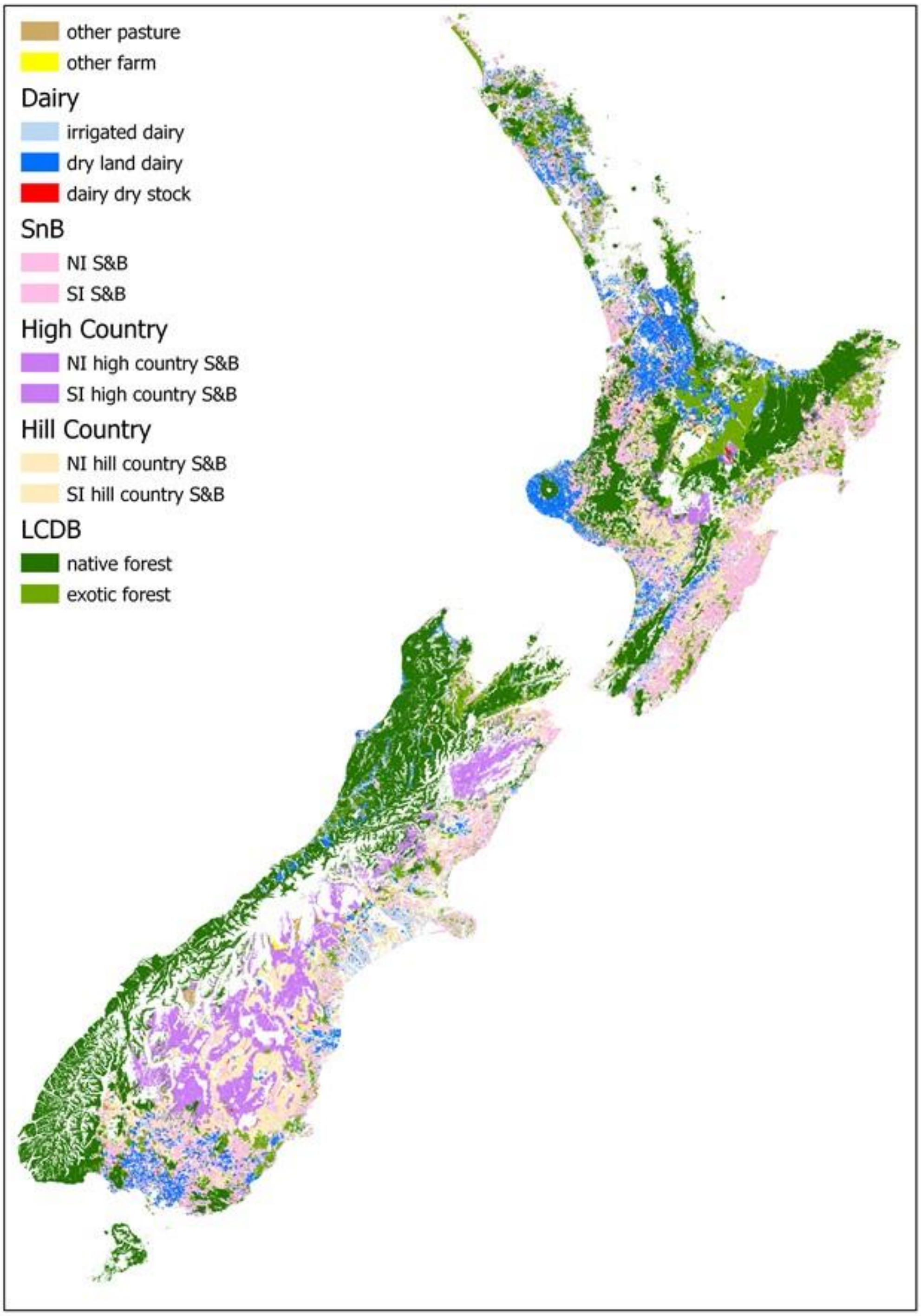

Figure 1. Geographic distribution of farm typologies in New Zealand. Sourced from AgriBase and Land Cover Database (Landcare Research, 2015).

Similar to FADN, AgriBase is survey-based and it provides data along the farm- and regional-type dimensions, covering approximately 90% of the total UAA. The description of each land parcel is maintained by Land Information New Zealand (**LINZ**). But unlike FADN, it doesn't collect financial data, such as the standard gross margin (**SGM**; calculated as *the value of an output minus the cost of variable inputs required to produce that output on a per ha basis*) that is used as a measure of farming intensity (Andersen et al., 2007), and it doesn't require a special weighting system such as the one used in FADN.

By overlaying the geospatially-referenced individual farms from AgriBase with additional geospatial information from the Land Resource Information (**LRI**) system (Landcare Research, 2017), specifically the Land Cover Database (**LCDB** v. 4.1) (Landcare Research, 2015), an indication of land area, land use capability (**LUC**), topography, predominant soil orders and drainage classes can be obtained for each farm. LCDB is a multi-temporal, thematic classification of New Zealand's land cover. It contains 33 mainland classes. Although the classification has evolved considerably, the backward compatibility has been maintained. Geographic features are described by a polygon boundary, a land cover code, and a land cover name; the data set is designed to complement in theme, scale and accuracy the LINZ 1:50,000 topographic database. Land Cover Database is suitable for use in national and regional monitoring on environmental performance, forest and shrub land inventory, biodiversity assessment, trend analysis and infrastructure planning. For more information, visit https://lris.scinfo.org.nz/layer/423-lcdb-v41-land-cover-database-version-41-mainland-new-zealand/.

Predominant topographies within a farm can be obtained by overlaying Agribase™ with slope data based on a digital elevation model (DEM; Landcare Research, 2017), and grouping them into four categories: Flat, 0 - 7°; Rolling, 8 - 15°; Easy hill, 16 - 25°; and Hard hill, >25°. This is particularly relevant to New Zealand's pastoral sector: flat to rolling country comprises about 55% of the area in improved pastures, whereas areas in slopes from 16 - 20° and >20° comprise about 13 and 32%, respectively (Hodgson et al., 2005). More vastly, only about a third of New Zealand's land area is classified as flat to rolling (slopes <16°). The remaining two-thirds are in easy (slopes >16°) to steep (slopes >25°) hills or mountains (Hodgson et al., 2005). Given the magnitude and land areas under slopes >25°, natural soil erosion continues to play a role in shaping certain New Zealand landscapes, especially those in more fragile ecosystems, such as steep hill country in the North Island.

Although beyond the scope of this Report, the land on each farm can be further characterised by identifying the predominant soil types, topography and drainage profiles. The main soil types on each farm can be defined using the New Zealand Soil Classification (**NZSC**) soil orders database (Landcare Research, 2017). The LUC, a land classification system, has been developed in New Zealand to assist sustainable management of farm enterprises (Lynn et al., 2009). The LUC classes are based on five factors including rock type, soil, slope angle, erosion type and severity, and vegetation cover. Using the LUC system, land is categorised into eight classes reflecting its potential sustainable use, with classes 1 - 7 as potentially suitable for pastoral grazing (Class 1 with the highest productive potential and Class 7 with the most limitations to pastoral use).

Although not used in the current geospatial modelling exercise, overlaying LUC Classes can potentially provide a farm-scale framework that can provide an indication of different farm production systems and performances, as well as changes over time, capturing the interactions between farm types, land use capabilities and production levels, as these influence environmental outcomes (Vogeler et al., 2014; Vibart et al., 2015). Furthermore, LUC has been linked to the major pastoral land users (sheep, beef, and dairy production) to estimate potential livestock carrying capacity (Vogeler et al., 2016), and indirectly, economic farm surplus (i.e. farm profit before tax in NZ$) as proxies for farming intensity.

b) Description of main farm types for New Zealand

New Zealand covers an area of 26.8 million hectares (ha), including minor islands, of which almost 14.0 million ha (52%) were farmed or in commercial forestry in 2016 (Statistics New Zealand, 2017b) (**Table 2**). In 2016, there were 55,473 farm holdings (Statistics New Zealand, 2017); the relative proportions of New Zealand's farm holdings by farming activity are reported in **Table 3**.

About 39% of the land mass classified as pastoral, and a further 1.1% as arable land, supported almost 70 million livestock, vastly ruminants, as major components of New Zealand's pastoral agriculture. Of these, 75% corresponded to sheep (including lambs marked and/or tailed), 16% to dairy cattle (including calves born to dairy cows and heifers), 5% to beef cattle, and 1% to deer livestock (Statistics New Zealand, 2017).

Table 2. Land cover in areas farmed in New Zealand.

Land cover of farmland	Area (million hectares)
Grassland	7.8
Tussock or danthonia	2.6
Plantations	1.6
Other land or holdings	2.0

Table 3. Major farm activity in New Zealand.

Farming activity	Proportion of farm holdings (%)
Sheep and beef	44
Dairy	21
Horticulture and orchards	15
Mixed livestock	6
Crop farming	5

The process for developing the farm typology is shown in **Figure 2**. Farm types are shown in green boxes. These types were selected because they represent the main land uses in New Zealand (**Table 4**). Sources of data on these farms, as described above, are designated in the figure by the blue boxes (Irrigation database, AgriBase, LCDB, DEM). Yellow boxes depict actions linking tools and pathways, such as overlay of databases, selection of land cover types, reclassification of shapes, and amalgamation of farm types. Obtaining areas in grasslands vs. those in native and exotic forests was one of the first steps in the pathway (Figure 2). Because of the lack of a comprehensive database of all farms, land cover, and geographic data, farm types were constructed from a number of sources, including sector bodies, described herein for each major land user.

A brief description of the major agricultural land users follows.

Sheep and Beef (**S&B**) farming, an aggregation of sheep, beef and mixed sheep and beef production continues to be the largest agricultural (and pastoral) land user in New Zealand (**Figure 3**). Sheep and beef farming is widespread throughout New Zealand.

Sheep and beef enterprises were spatially and socioeconomically modelled in a step-wise fashion. First, because few farmers in New Zealand devote themselves exclusively to beef production, and sheep farmers often carry a beef herd, even if in small numbers, we opted to cluster sheep, beef, and mixed sheep and beef enterprises as mixed sheep and beef production (Beef and Lamb New Zealand, 2017).

Second, AgriBase provides a spatial reference for the predominant farm type, both in terms of area devoted and as the main source of income. For sheep and beef systems, it only provides a spatial reference for generalised 'Beef cattle farming', 'Sheep farming' or 'Mixed sheep and beef farming', but it does not provide a measure of distinction in terms of farm management, livestock policy and farming intensity. These measures were provided by Beef and Lamb New Zealand (B+LNZ) with the inclusion of farm classes across the entire country (Beef and Lamb New Zealand, 2017).

Third, these systems needed to be spatially referenced and somewhat simplified across a vast array of S&B systems. In doing so, the location of S&B farms across both islands remained a feature (Figure 1), but the eight S&B farm systems were reduced to six (

Table 4). Altitude, and to a lesser extent topography, served as both typology boundaries and spatial references for the six S&B farm types chosen; corresponding lowland, hill country and high country farms were assumed to be at 0 – 300, 300 – 600 and >600 m above sea level. These boundaries also provided a coarse estimate of potential pasture production and livestock carrying capacity (Gillingham, 1973; Hodgson et al., 2005), in turn associated with farm net revenue. Conveniently dividing New Zealand grasslands on the basis of elevation and topography into three groups (in our case per Island), is in agreement with previous attempts to categorize the main livestock/land use activity across the country (Bryant and Sheath, 1987; Hodgson et al., 2005).

Fourth, in addition to the need for spatial referencing, the simplification process was driven by the need to provide a measure of intensity, measured here as *net revenue* or *farm profit before tax* (herein farm profit; *calculated as total gross revenue minus total working expenses and total standing charges exclusive of tax*). According to farm profit (intensity), all S&B farm typologies are considered to be of low intensity. Occasionally, given certain market and production conditions, lowland mixed cropping and lamb- and beef-finishing systems can become of medium intensity (farm profit ≥ 750 and < 4500 NZ$/ha) (Beef and Lamb New Zealand, 2017).

Table 4. Major land uses and farm types for New Zealand.

Farm types	Source
Sheep and beef[1] – NI[2] lowlands	AgriBase, B+LNZ
Sheep and beef – NI hill country	AgriBase, B+LNZ
Sheep and beef – NI high country	AgriBase, B+LNZ
Sheep and beef – SI[3] lowlands	AgriBase, B+LNZ
Sheep and beef – SI hill country	AgriBase, B+LNZ
Sheep and beef – SI high country	AgriBase, B+LNZ
Dairy – Irrigated	AgriBase, DairyNZ
Dairy – Non irrigated	AgriBase, DairyNZ
Dairy[4] – Dry livestock	AgriBase, DairyNZ
Native forest	LCDB
Exotic forest[5]	LCDB
Other pastoral-type farms[6]	AgriBase
Vineyards	AgriBase, StatsNZ
Arable crops (non-livestock)[7]	AgriBase
Other farms (horticulture, orchards, other)	AgriBase

[1]S&B: Sheep and beef farms. [2]NI: North Island. [3]SI: South Island. [4]Dairy support areas for non-lactating dairy livestock. [5]Commercial forestry. [6]Areas in grasslands beyond S&B and Dairy. [7]Arable cropping and seed production (See **Appendix 1** for more detail).

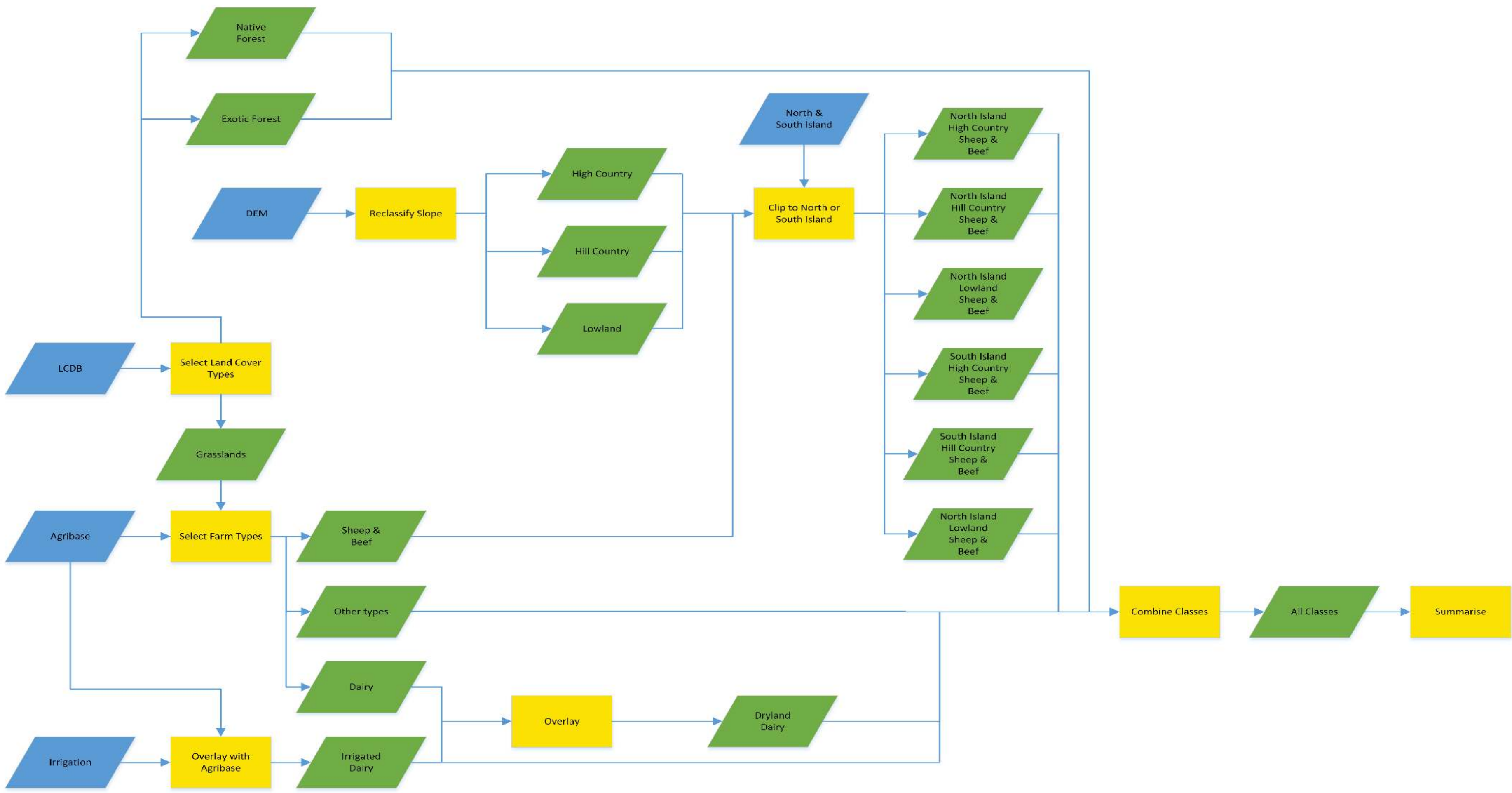

Figure 2. Tools and pathways to New Zealand farm typology. Green boxes outline farm typologies (obtained in an iterative fashion) whereas blue boxes depict tools and databases used in the multi-layer modelling and yellow boxes portray actions linking tools and pathways. DEM: Digital elevation model (Landcare Research, 2017).

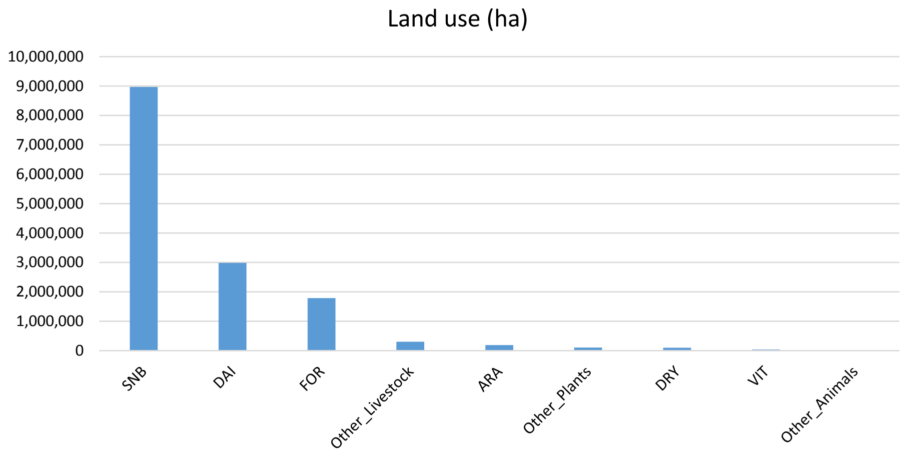

Figure 3. *Land use in New Zealand (from AgriBase™).*

The AgriBase categories included in each of these land-use classifications are described in **Table 5** below. See Appendix 1 for more detail.

Table 5. Source categories from AgriBase for Land-use classification.

Land-use classification	*AgriBase categories*
SNB – Sheep and Beef	Beef
	Sheep
	Mixed sheep and beef
DAI – Dairy	Dairy cattle farming
FOR – Forestry	Commercial forestry
Other Livestock	Alpaca
	Deer
	Goats
	Horses
	Pigs
	Other Livestock
ARA – Arable	Arable cropping or seed production
Other Plants	Flowers
	Fruit growing
	Plant nurseries
	Other planted types
	Vegetable growing
Dry – Dry dairy cows	Non-lactating dairy farming (dairy support)

Viticulture	Grape growing and wine
Other animals	Apiculture Dogs Emu bird farming Ostrich bird farming Poultry farming Zoological gardens

Table 6. Characteristics of sheep and beef (S&B) farm classes from the 2014-15 survey by Beef and Lamb New Zealand (B+LNZ), farming intensity (farm profit before tax; B+LNZ Economic Service) and farm types used in this Report.

Beef and Lamb New Zealand					*TSARA Report*	
Class	Location	Description	% farms[1]	Profit (NZ$)[2]	Description	Intensity[3]
1	S. Island	High country	2	16	SI – High country	Low
2	S. Island	Hill country	7	57	SI – High country/Hill country	Low
3	N. Island	Hard hill country	9	182	NI – High country	Low
4	N. Island	Hill country	32	207	NI – High country/Hill country	Low
5	N. Island	Intensive finishing	11	253	NI – Lowlands	Low/Medium
6	S. Island	Finishing/breeding	22	151	SI – Lowlands	Low/Medium
7	S. Island	Intensive finishing	11	252	SI – Lowlands	Low/Medium
8	S. Island	Mixed finishing	4	435	SI – Lowlands	Low/Medium

[1]Source: B+LNZ http://beeflambnz.com/farm-classes/ [2]Farm profit before tax (NZ$/ha; 2015/2016) = total gross income – (total working expenses + insurance, levies, rates, interest, and rent) (B+LNZ Economic Service). Last updated: April 2017. [3]Intensity (farm profit per hectare): Low (farm profit <750 NZ$/ha); Medium (farm profit ≥750 and <4500 NZ$/ha); High (farm profit >4500 NZ$/ha).

The B+LNZ classification can be linked to the wider TSARA modelling through the profitability variable. The EU-TSARA project uses net revenue per hectare as the measure of intensity. The B+LNZ data contains data on net revenue per hectare that classifies it as low intensity by the EU-TSARA measure. This will allow the B+LNZ classification to be used to generate farm types for New Zealand as described in

***Table* 6** above and to be modelled alongside EU data.

A brief description of B+LNZ farm classes follows.

South Island high country (B+LNZ Class 1)

The South Island high country farm systems are extensive and dominated by high altitude tussock grasslands. Improved pastures are limited to flat and rolling land on a limited area of valley bottoms and old river terraces. Properties can range in size from 3,000 to 40,000 ha (Moot et al., 2009). Traditionally, these are fine wool producing farms located mainly in Marlborough, Canterbury and Otago (Beef and Lamb New Zealand, 2017).

South Island hill country *(B+LNZ Class 2)*

Unreliable pasture growth in summer months reflects seasonal variation in the rainfall distribution combined with high evapotranspiration and low soil water holding capacity due to a high proportion of stones within the profile and/or shallow depth to underlying gravel. These effects are exacerbated by the presence of shallow, weakly developed soils that dominate on the eastern foothills of Marlborough, Canterbury and Otago. About 75% of the livestock units that are carried through the winter are sheep and 25% are beef cattle (Beef and Lamb New Zealand, 2017).

North Island hard hill country (B+LNZ Class 3)

These properties are often in slopes >16°, with low fertility soils on the east and west coasts and Central Plateau of the North Island. Pasture improvement has been possible with the widespread use of aerial fertilisation with superphosphate and broadcasting with improved pasture species (Moot et al., 2009). These low fertility soils are maintained by regular aerial applications of lime and superphosphate when these alternatives become financially feasible.

North Island hill country (B+LNZ Class 4)

These farms are often smaller than those on hard hill country and are more productive on a per unit area basis. Soils are of moderate-to-high fertility resulting from lime and fertilizer inputs over time, with feed deficits occurring in summer months as pasture production is compromised by soil moisture deficits. These farms carry between 7 - 13 stock units per ha, with a high proportion of livestock sold in prime condition (Beef and Lamb New Zealand, 2017). Stock units are a common measure used to express livestock stocking rate; one stock unit (**SU**) represents the amount of feed to carry a ewe and her lamb on an annual dry matter basis (1 SU = 550 kg DM).

North Island intensive finishing farms (B+LNZ Class 5)

Farms that belong to this B+LNZ class are scattered throughout the North Island. These farms are of high fertility, with a flat-to-rolling contour, and are capable of producing >12 tonnes of DM per ha annually from predominantly perennial ryegrass/white clover pastures. These farms carry between 8 - 15 stock units per hectare. A high proportion of stock is finished on-farm, and breeding replacements are often purchased and brought in (Beef and Lamb New Zealand, 2017).

South Island finishing-breeding farms (B+LNZ Class 6)

These farms belong to a more extensive type of finishing, and may encompass some irrigation units in drier areas with some cash cropping. Carrying capacity of these farms ranges from six to 11 stock units per hectare on non-irrigated farms and >12 stock units per hectare on irrigated units. This is the dominant farm class in the South Island, located mainly in Canterbury and Otago (Beef and Lamb New Zealand, 2017).

South Island intensive finishing farms (B+LNZ Class 7)

These farms are mostly found in summer-moist environments in Southland and South and West Otago where sufficient summer rainfall prevents severe droughts. Winters, however, can be severe. These high-producing grassland farms carry about 10 - 14 stock units per hectare, along with some cash crops (Beef and Lamb New Zealand, 2017).

South Island mixed cropping and finishing farms (B+LNZ Class 8)

These farms are located mainly on the Canterbury Plains, where irrigation is usually available. A high proportion of the revenue of these farms is from grain production (i.e. wheat, barley, oats) and small seed production (both fodder and vegetable seed), as well as finishing livestock (Beef and Lamb New Zealand, 2017).

Dairy enterprises were also spatially modelled in a step-wise fashion. First, AgriBase only provides a spatial reference for generalised 'Dairy cattle farming' (Appendix 1), but as with S&B farms, it does not provide a measure of distinction in terms of dairy farm management, livestock policy and farming intensity. These measures were provided by DairyNZ (DairyNZ Economic Survey, 2017), across their dairy farm systems classification (DairyNZ, 2010) (**Table 7**). DairyNZ's Economic Survey outcomes that are relevant to this Report are largely derived from DairyBase®, which categorises farms into five production systems based at large on the quantity of feed purchased (imported to the farm) and the timing and use of imported feed. Based on these characteristics, farm systems are further collated to yield three categories: Low input (Systems 1 and 2), Medium input (System 3), and High input (Systems 4 and 5) (Table 7). Within each system, a wide variety in milk solids (**MS**; milk fat + milk crude protein) production and profitability exists. Furthermore, production system is a poor indicator of profitability. Expectedly, profitability is largely related to management, MS price and costs across production systems (DairyNZ Economic Survey, 2017)

Second, DairyNZ's farm systems needed to be spatially referenced and somewhat simplified across a vast array of dairy farm systems. In doing so, the location of dairy farms across the country remained a feature (Figure 1), but the five DairyNZ farm systems were reduced to two (non-irrigated, irrigated), as a simple measure of the need for supplemental water in these systems. As new technology arises improving the way dairy farmers irrigate, the demand on freshwater resources nationally and regionally also continues to grow. The South Island encompasses about 80% of the total irrigated land in dairy, with Canterbury and North Otago accounting for the majority of the area under irrigation (DairyNZ, 2017).

Third, according to the 2015-16 season farm profit, these enterprises would be considered of low intensity. However, in 2015-16 New Zealand dairy farmers received the lowest milk prices in over two decades (NZ$3.9/kg MS, compared with a long-term average price >NZ$6.0/kg MS) (DairyNZ Economic Survey, 2017). Consequently, farm profit for that season is a poor reflection of long-term dairy farm profit. Rather, given the long-term profit of New Zealand dairy farms, these should be categorised as being of medium intensity (farm profit ≥750 and <4500 NZ$/ha), and occasionally, high intensity (farm profit >4500 NZ$/ha) when high input farms and/or high-producing pasture land with optimal pasture utilization and management occur in synchrony with convenient supplement-to-milk price ratios and extremely high MS prices.

In addition, AgriBase provides a spatial reference for dairy 'Dry' enterprises (dairy support areas where non-lactating dairy livestock are either reared or kept during winter periods when pasture growth is at its minimum and soil pugging is frequent). These areas only account for *specific* dairy support (areas that have been deemed as the predominant farm type and source of income), and do not reflect/capture the vast majority of areas in dairy support. These areas appear as Dairy dry stock in Figure 1.

Table 7. Characteristics of dairy farm systems (DairyNZ, 2010), farming intensity (DairyNZ Economic Survey, 2017) and farm typologies used in this Report.

DairyNZ			TSARA Report	
System	Description	Profit (NZ$)[1]	Intensity[2]	Intensity (longer term)[3]
1	Self-contained (no feed imported), all livestock on the dairy platform (no dairy support required)	244	Low	Medium
2	~4 – 14% of total feed is imported. Most non-lactating cows (winter) are sent off-farm		Low	Medium
3	~10 – 20% of total feed is imported, mostly to extend lactations and for non-lactating cows	-106	Low	Medium/High
4	~20 – 30% of total feed is imported, used at both ends of the lactation and for non-lactating cows	-260	Low	Medium/High
5	~30 – 50% of total feed is imported, used throughout the lactation and for non-lactating cows		Low	Medium/High

[1]Farm profit before tax (NZ$/ha; 2015-2016) = dairy gross revenue – dairy operating expenses (DairyNZ Economic Survey, 2017). [2]Intensity (2015-16; NZ$/ha): Low (farm profit <750 NZ$/ha); Medium (farm profit ≥750 and <4500 NZ$/ha); High (farm profit >4500 NZ$/ha). [3]Intensity (longer term; NZ$/ha).

Forestry is a major part of New Zealand's land use and economy (Figure 3); wood and wood products are New Zealand's third largest export earner behind dairy and meat (MPI, 2017). New Zealand's forest resources cover >8 million ha (29% of the country's total land area). Of these, indigenous forests account for the majority (about 6.3 million ha), with planted production forest accounting for the remaining 1.7 million ha (Statistics New Zealand). Forests are defined here as occupying an area >0.5 ha and an actual (or potential) minimum height of 5 m at maturity; scrub, mangrove, orchards or linear tree features, such as trees bordering roads and rivers, are not included. It does, however, include tree shelterbelts with an area >0.5 ha and a width >20 m. Indigenous forests are widespread throughout New Zealand, but they are particularly dominant on the mountain slopes of the West Coast and Fiordland areas of the South Island. Approximately 77% of New Zealand's indigenous forests are Crown-owned, the vast majority of which constitute areas for conservation, heritage and recreation uses. The remaining 23% of indigenous forests are privately owned (Statistics New Zealand).

Exotic (commercial) forests have been planted in New Zealand since the early 20th century and are found scattered throughout the country. About a third of the area in exotic forest is located in the central North Island; other major forest growing areas include Northland, East Coast, Hawkes Bay, Nelson, Marlborough, Otago and Southland. The dominant species is radiata pine (*Pinus radiata*), accounting for about 90% of the total area in exotic forests. Douglas fir (*Pseudotsuga menziesii*) and a variety of eucalyptus (*Eucalyptus spp.*) amongst other tree species, largely account for the remaining area (MPI, 2017). In 2016, areas planted in production forest, areas replanted in production forest and areas of exotic timber harvested accounted for 3,675, 37,825 and 47,492 ha, respectively (Statistics New Zealand).

Although export earnings per ha in 2015-16 would place S&B, dairy and commercial forestry as being of Medium (NZ$1,470/ha), High (NZ$6,328/ha) and Medium (NZ$2,819/ha) intensity (Statistics New Zealand), a measure of intensity based on *current* farm profit (as described above) largely categorizes these activities as Low, Medium and Low intensity, respectively.

c) Data available about farm types and correspondence with TSARA

As indicated above, New Zealand lacks a comprehensive database of all agricultural farms. The lack of an FADN-equivalent knowledge base, particularly in its socioeconomic assessment, requires that farm types be constructed from a large number of sources above and beyond spatially-referenced land covers. Prior attempts to match and integrate agricultural land databases in New Zealand (i.e. exploring the presence of statistically-robust relationships between agricultural land use and freshwater quality changes) have proven to be more complex, and presumably of less value, than envisaged at the time (Statistics New Zealand, 2017a).

A number of datasets were used to characterise farm types in terms of spatial, biophysical and socioeconomic factors in this Report. So far, the greatest challenges to create a farm typology in a similar approach to that of the EU (Andersen et al., 2007) reside in the following:

a) validating data in AgriBase (a voluntary system that includes data on the predominant farm type) with other sources of information (e.g. Statistics New Zealand and Agricultural Production Statistics, a periodically-reported database that identifies changes in the agricultural sector for planning and forecasting purposes);
b) the lack of socioeconomic data linked to spatial data. Ideally, if this information could also integrate socioeconomic factors that better characterise farming intensity in a spatial fashion, we would be in a better position to match current EU TSARA farm typology requirements.

3.2.3 Discussion of the proposed NZ AEZ

a) Data sources

Land Environments of New Zealand (**LENZ**) provides an environmental classification of New Zealand based on a set of 15 underlying data layers (Leathwick et al., 2002). Designed originally as a framework for addressing a range of conservation and resource management themes across the country, LENZ reveals a wider global trend towards ecosystem-oriented approaches to resource management. In New Zealand, this trend is evident in light of the growing relevance of ecosystems and their integrated management in legislation such as the Resource Management Act (1991).

Two main features distinguish LENZ from previous ecological classification efforts conducted in New Zealand.

First, LENZ uses numerical data layers describing various aspects of New Zealand's climate (seven layers), landforms (a slope layer) and soils (seven layers). Estimates of climate derived from long-term meteorological station data were coupled with soil attributes derived mostly from the New Zealand Land Resource Inventory (**NZLRI**; Landcare Research).

Second, LENZ uses a computerised classification procedure. Using this approach, similar environments can be identified, including small distinctive environments that are otherwise easily overlooked, regardless of their geographic location.

The numerical data layers describing various aspects of New Zealand's AEZ include climate, landforms, and soil characteristics, are outlined in **Table 8**. The seven climate layers used in LENZ are derived from mathematical surfaces (thin-plate splines) that use information about climate, location and elevation of a number of meteorological stations. The slope data layer used in LENZ was created from a 25-m DEM fitted to 20-m digital contour data using software developed at Landcare Research. The seven layers used to describe soil attributes in LENZ rely heavily on data from the NZLRI database. The development of this national database started over five decades ago, and describes New Zealand's land resources, with the overall objective of improving patterns of land use (Leathwick et al., 2002).

Table 8. Underlying data layers of the Land Environments of New Zealand (LENZ) (Leathwick et al., 2002).

Variable	Data layers	Reason to incorporate
Climate	Mean annual temperature	Impact on plant productivity
	Mean min. winter temperature	Impact on plant survival
	Mean annual radiation	Impact on potential plant productivity
	Min. winter solar radiation	Lowest solar radiation input
	October vapour pressure	Air dryness – evaporation from plants
	Monthly water balance ratio	Indication of site wetness
	Annual soil water deficit	Extent of drought limitation
Landform	Slope	Major driver of drainage and microclimate
Soils	Drainage	Oxygen availability in soil upper layers
	Acid-soluble phosphorous (P)	Critical soil nutrient
	Calcium	Nutrient and soil weathering
	Particle size	Rates of soil formation and nutrient release
	Induration	Soil resistance to weathering
	Age	Recent, more fertile vs. older, less fertile soils
	Chemical limitations to growth	Presence of salinity, ultramafic substrates

b) Proposed structure of the AEZ

LENZ provides a series of four hierarchical classifications that identify similar environments based on climate, landform, and soils, with 20, 100, 200, and 500 environments across the country for LENZ levels 1, 2, 3, and 4, respectively. The hierarchical nature of such classifications allows for results to be displayed at widely varying levels of detail, in turn facilitating their use over a wide range of map scales (1: 5,000,000 to 1: 50,000) (Leathwick et al., 2002). For the purpose of this Report, we chose Level I (20 zones) to characterise New Zealand AEZ (***Figure 4***); further detail is beyond the scope of this Report.

The concept of environmental distance is central to the classification process used to define LENZ-derived AEZ. Given two data points, each driven by an amalgamation of environmental variables, the environmental distance between these points is the difference in environment, averaged across all environmental variables. Such measures are widely used in a range of multivariate clustering techniques (Hazeu et al., 2010).

It should be noted that the results of such clustering analysis depend heavily on the units used for the different variables. Because the analysis involves establishing the distances between data points comprised of variables using different scales that are usually not comparable, the choice of unit will often be determinative in how data points cluster together once more than two variables are included. The LENZ classification addresses this issue by weighting each variable according to the range of its values. LENZ uses a modified weighting system that gives equal weight to each of the seven climate variables and the variables describing slope, drainage, soil age, and chemical limitations, while the four soil variables are given a lesser weighting (Leathwick et al., 2002).

Briefly, the arrangement of environments A to T form an array from the northern lowland environments (A) with warm temperatures and high solar radiation to the steep, cold environment of the South Island's Southern Alps (T) (**Table 9**). Within the 20 environments, five clusters emerge (Leathwick et al., 2002):

Environments A to F are widespread in the North Island and the north and east of the South Island and typically have warm temperatures, moderate to high solar radiation, low monthly water balance ratios, low to moderate water deficits and moderately-to-high vapour pressure deficits (Figure 4). The vast majority of soils are mature, with the most common soil parent materials being rhyolitic rock and tephra from the Taupo volcanic zone; andesitic rock and tephra from the Tongariro and Taranaki volcanoes; and greywacke rock, mostly along the main mountain ranges with scattered outliers in western Waikato and Northland.

Environments G to K are present throughout the North Island and the eastern South Island, and consist predominantly of recent soils of flood plains, sand dunes or recent volcanic deposits (Figure 4). Although much less extensive than Environments A to F, they share strong similarities in climate. Alluvium from a variety of sources is the most widespread parent material.

Environments L to N comprise extensive areas of outwash glacial material and alluvium in the southern and eastern South Island, with more scattered occurrences on the South Island's West Coast (Figure 4). Climates in these environments are cooler than in more northern environments, with much lower solar radiation. Average monthly water balance ratios and October vapour pressure deficits vary widely, with sites east of the Southern Alps much drier than those in the west and south. The most common parent materials are loess and alluvium from greywacke or schist, with smaller areas of alluvium from granite, basic volcanic rocks and/or younger Tertiary rocks.

Environments O to S occupy the higher mountain ranges and central volcanoes of the North Island and the extensive mountainous terrain of the South Island (Figure 4). Climates are generally cool, with only low to moderate solar radiation, low deficits of rainfall and vapour pressure, and high average monthly water balance ratios. Slopes are moderate to steep. The most widespread soil parent materials are greywacke in the mountains of Canterbury, Marlborough and the North Island main ranges; schist in the mountains of Otago and along the eastern side of the South Island's main alpine fault; gneiss and granite on Stewart Island, in Fiordland, scattered along the South Island's West Coast and in Buller and Nelson; and Tertiary rocks, mostly in Buller and west Nelson.

Environment T consists of the permanent snow and ice of the South Island's Southern Alps, occurring mostly at high elevations where the climate is cold and wet, and slopes are mostly steep.

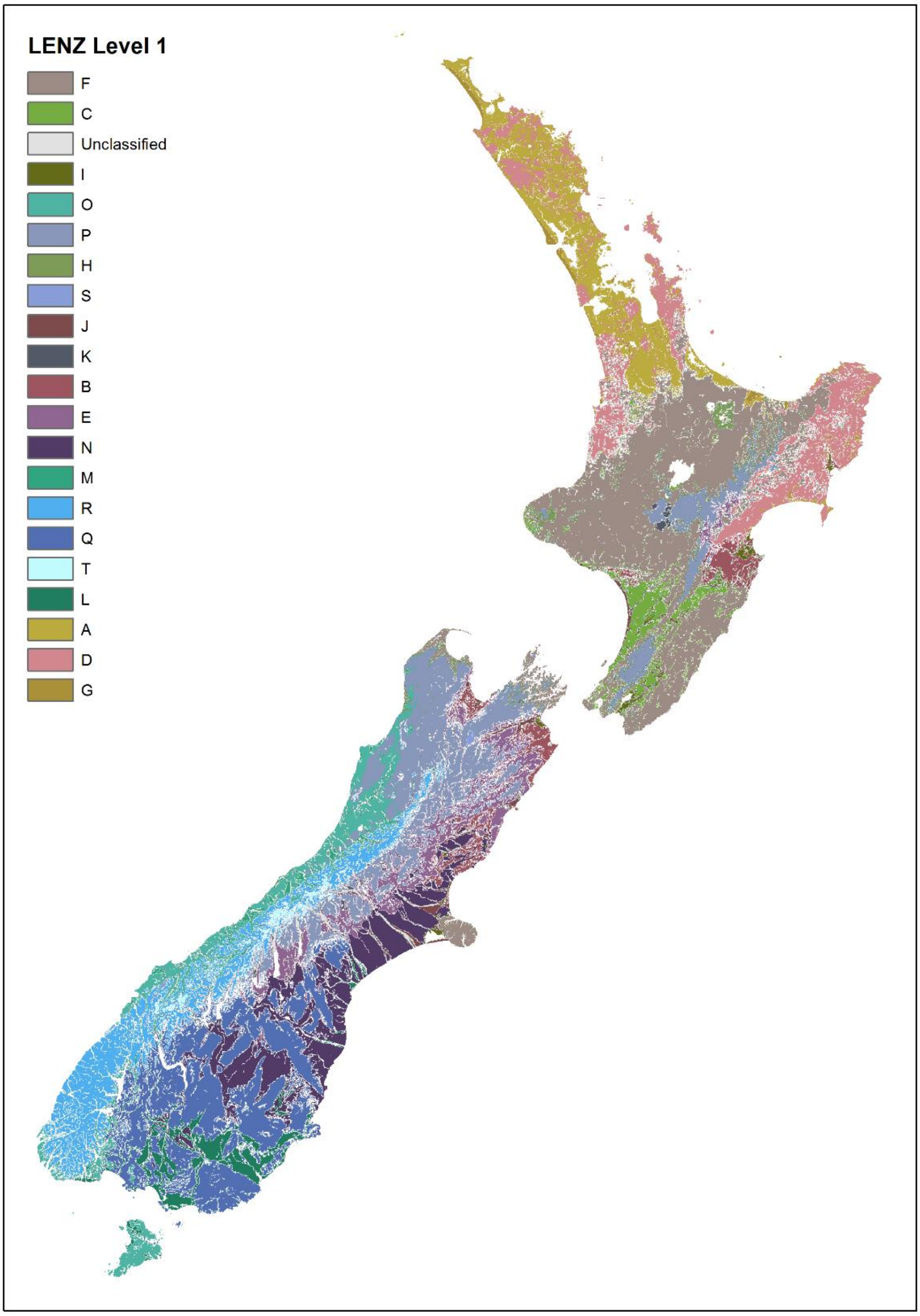

Figure 4. Land Environments of New Zealand (LENZ; Level I) (Leathwick et al., 2002).

Table 9. Land Environments of New Zealand (LENZ) Level I environments (Leathwick et al., 2002). Total area in LENZ = 26,106,665 ha.

Environments	Description	Area LENZ (ha)	Area AgriBase (ha)
A	Northern lowlands	1,859,882	1,547,940
B	Central dry lowlands	693,113	641,722
C	Western and southern North Island	639,190	558,166
D	Northern hill country	2,103,568	1,980,021
E	Central dry foothills	1,327,297	1,285,409
F	Central hill country and volcanic plateau	5,252,578	4,948,307
G	Northern recent soils	344,076	278,044
H	Central sandy recent soils	137,283	132,584
I	Central recent poorly-drained soils	122,642	101,557
J	Eastern dry recent soils	297,207	236,000
K	Central cold recent soils	163,426	144,705
L	Southern lowlands	812,067	715,902
M	Western South Island recent soils	228,738	201,575
N	Eastern South Island plains	2,053,562	1,897,761
O	Western South Island foothills and	1,422,548	1,434,327
P	Central mountains	3,252,370	3,432,267
Q	South-eastern hill country and mountains	3,275,778	3,156,145
R	Southern Alps	1,930,806	1,935,753
S	Ultramafic soils	33,519	32,157
T	Permanent snow and ice	157,015	157,130

LENZ Level I was chosen as the spatially-referenced database to provide relatively homogenous agronomic landscapes (AEZ) for this work because:

1. the approach followed by LENZ includes relevant and numerical underlying layers that provide discrete and relatively uniform environments;
2. by focusing on the more stable abiotic ecosystem components as a basis for classification, LENZ provides a framework to characterise the broad potential biological conditions at any given site;
3. the dynamic nature of domestic ecosystems, as in most other parts of the world, is further heightened by human-related disturbance; for New Zealand, both the clearance of former native land cover and the introduction of new species are particularly relevant to this disturbance, and these aspects are acknowledged by the LENZ database.

Expectedly, as with many other databases, the LENZ database has temporal scale limitations; most of the underlying data used to define the climate layers were composed over the period 1950 – 1980, whereas soil data were collected over the last five decades. This may be seen as representing a snapshot in time of New Zealand's environment, potentially aggravated by considerable uncertainty over the likely magnitude of changes in climate over the next decades. In spite of this limitation, LENZ provides discrete and relatively uniform areas in an environmental space, and many of these environments show a wide geographic dispersion. Although some may form one or two discrete geographic patches, many occur as small patches, often scattered over a considerable area. In this context, LENZ represents, in a more accurate fashion, the environmental variation across New Zealand's landscapes.

Native bush was added to the environments to reflect its presence throughout the New Zealand landscape. In most environments, the combined S&B typology is the largest land user (**Figure 5** and **Figure 6**); dairy was the largest agricultural land user in one of the environments (Western South Island recent soils; M) (Figure 6), but only as a minor fraction compared with the presence of native bush. Dairy was the second largest agricultural land user after S&B in many environments (A, C, G, I, J, L, N). Exotic forestry was also a major land user in most environments.

The last three environments (R, S, and T) are either marginal or not agronomically suitable for agriculture (Table 9). The combined S&B typology was the largest agricultural land user (expressed in ha) in these environments, but it only accounted for 4, 3, and 3 per cent of land use in environments R, S, and T, respectively, followed by exotic forestry (1 per cent of land use in environment S).

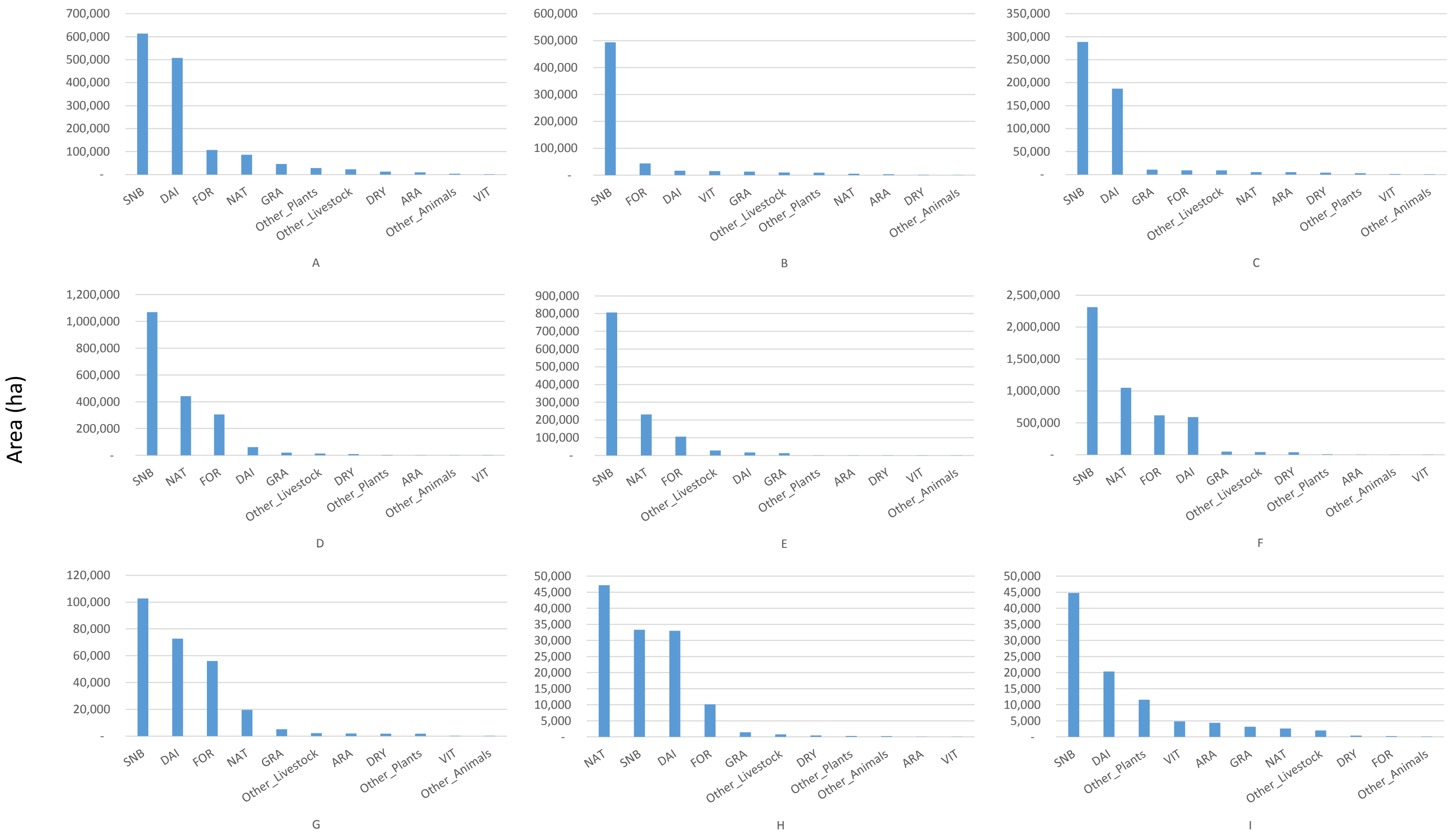

Figure 5. Farm typology areas (in ha) within each of LENZ Level I environments A to I (see Table 9 for LENZ description and Appendix 1 for more detail on farm typology).

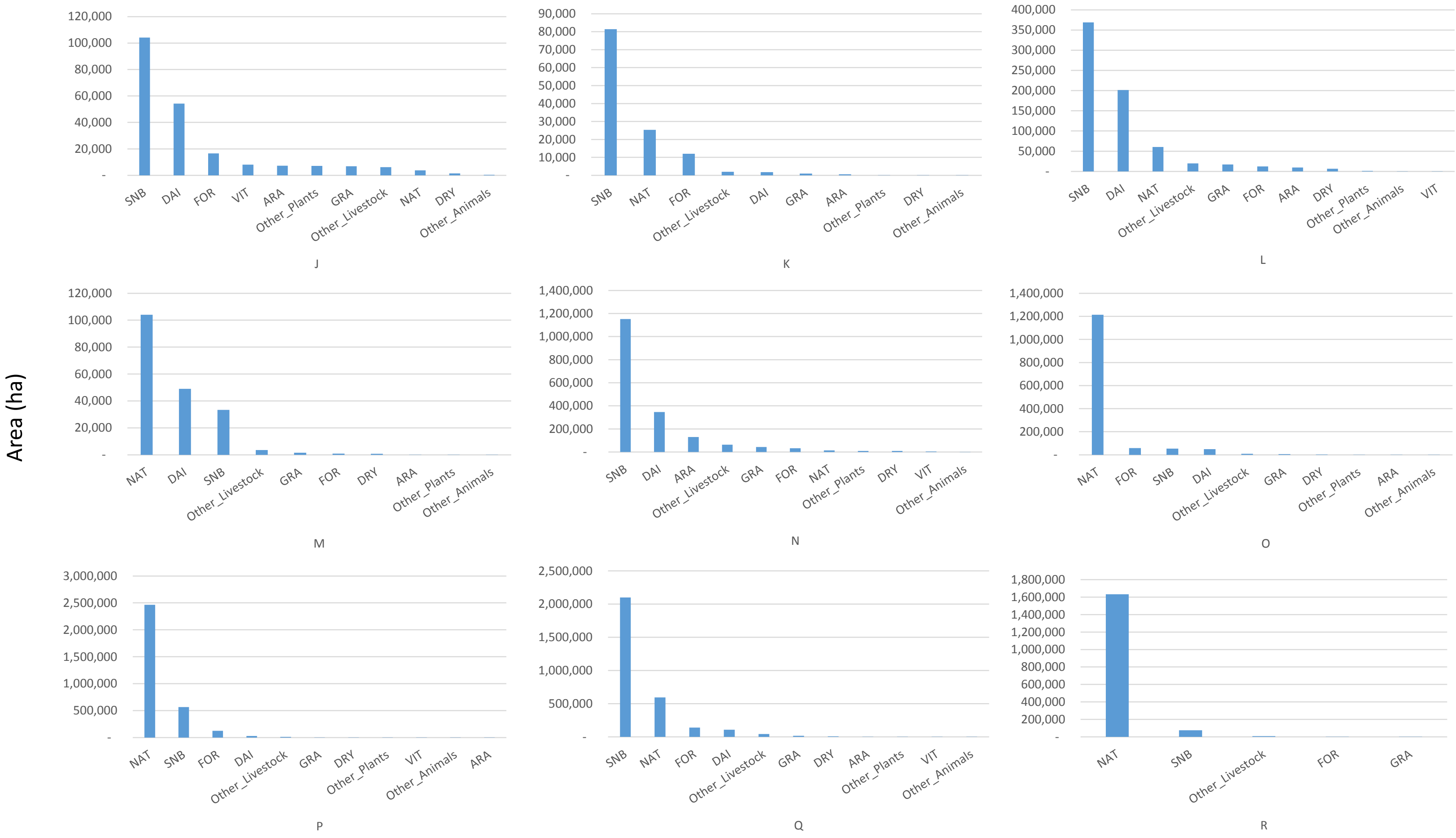

Figure 6. Farm typology areas (in ha) within each of LENZ Level I environments J to R (see Table 9 for LENZ description and Appendix 1 for more detail on farm typology).

3.3 Assessment of the New Zealand approach

3.3.1 Differences with TSARA modelling

Pastoral agriculture is a major land user in New Zealand, and the livestock (ruminants in particular) grazing the pastoral landscapes play a critical role in New Zealand's economy, social praxis, culture and heritage. Expectedly, the databases assembled in the construction of the European AEZ (Hazeu et al., 2010) and how these capture EU farm typologies (Andersen, 2017) vary from those used to construct New Zealand's AEZ and farm typology (i.e. landscape variables measured or predicted, data availability, clustering criteria). As mentioned above, compared with the FADN database, AgriBase only provides a spatial reference for the predominant farm type, both in terms of area devoted and as the main source of income, without a clear distinction in terms of farm management, livestock policy and farming intensity. But unlike FADN, AgriBase accounts for most farm holdings in New Zealand, and does not require a special weighting system.

Although beyond the scope of this Report, land use capability, as defined earlier, can aid in obtaining an improved measure of intensity (Vogeler et al., 2016). The degree of linearity of this response (LUC-derived pasture production vs. livestock carrying capacity) can then be discussed with experts in the field, to obtain an improved measure of farming intensity. The analysis, however, is of greater complexity and may trigger considerable debate, particularly in cases where large amounts of supplements are brought into the farm (e.g. intensified dairy farm systems). Another option is to use animal numbers and areas in farm activities other than the predominant farm type (provided for each farm ID by the extended AgriBase database) (**Appendix 2**), and/or farm inputs (i.e. amounts of fertiliser applied, amounts of supplements fed) to provide for a better indication of intensity.

The categorisation of the European AEZ in TSARA are based on a number of underlying databases including land cover, altitude, landform (mean slope), climate-related variables (number of days >5°C as a measure of mean growing season; mean temperature range; sum of rainfall deficit for May, June and July as a measure of summer drought), and soil-related variables (soil texture, soil water holding capacity, plant rooting depth) (Hazeu et al., 2010). Similarly, the characterisation of LENZ as a first approximation to New Zealand's AEZ includes similar variables that affect soil nutrient availability, plant productivity and plant survival (Table 8).

From the data sources compiled to obtain the AEZ (both EU and NZ), the use of a suitable topsoil (0 – 30 cm) organic carbon (**C**) dataset (i.e. for the assembly of EU-AEZ) is probably the greatest difference between both approaches. A comprehensive principal component analysis (**PCA**) of several soil variables suggested that topsoil organic C content was the preferred variable to differentiate soils in Europe (Hazeu et al., 2010). It is important to note that although OCTOP is a continuous variable, it has been grouped into six classes, and variation in soil properties within each class is likely to occur (Hazeu et al., 2010).

A recent, comprehensive analysis of large soil datasets in New Zealand revealed large and significant gaps in understanding the magnitudes of change in soil C (and associated uncertainties) as well as the lack of representativeness of existing soil sampling data (Schipper et al., 2017). Overall findings from a number of well replicated, long-term trials throughout New Zealand suggested that i) sporadic pasture renewal and associated cultivation is unlikely to affect soil C stocks in a significant fashion, in contrast with general C losses due to frequent and repeated cultivation, ii) the effect of different stocking types or stocking rates on soil C stocks continues to be poorly understood, iii) there is strong evidence that soil C stocks are lower under irrigated than neighbouring dryland pastures, and iv) there is some evidence suggesting that fertiliser inputs to tussock grasslands increases C stocks (Schipper et al., 2017). Put together, the current understanding provides a more generalised view that while there are some small changes in C stocks under pasture, by enlarge these stocks are very resilient to change. Land under permanent or more regular cropping offers a different story.

Notwithstanding these limitations, recent work has focused on improving the precision of estimates of soil C stocks (McNeill et al., 2014; Schipper et al., 2017), in recognition that certain fundamental land-use practices and soil orders require further information on soil C stock changes. But as it currently stands, soil C estimates are based at large on land use, and a map of soil C stocks would mirror a map of land use and would not meaningfully contribute to a model or indicator that already accounts for land use (Deborah Burgess, Ministry for the Environment, LUCAS Team, personal communication). For these reasons, we have not included soil C as one of the variables to be used in New Zealand.

3.3.2 Similarities with TSARA modelling

The benefits of developing agricultural landscapes that include both the natural environment (i.e. an amalgamation of climate, landform, and soil characteristics) and farming activities to describe the scale and heterogeneity of AEZ have been discussed elsewhere (Termorshuizen and Opdam, 2009; Rizzo et al., 2013; Andersen, 2017). As with the EU (Hazeu et al., 2010), the design of a **AEZ(farm)** typology (farm types spatially referenced within each AEZ) provides a reliable framework and a first step for agri-environmental modelling at the landscape level in New Zealand. Although the obtainment of hierarchical and agronomically homogenous units requires further work, the spatial amalgamation of farm and AEZ layers used here seem detailed enough to account for the wide spectrum of biophysical environments across the country while simultaneously being capable of providing modelling outcomes. However, it has yet to be shown that the selected method is sufficiently generic, operational and flexible to fit the TSARA typology modelling criteria.

Different spatial frameworks and threshold values can vary depending on the scale and scope considered, and may have to be tailored specifically for the AEZ(farm) typology of New Zealand. Diverse landscapes provide many vital services and processes including preservation of biodiversity, nutrient cycling, pollination, aesthetic values, amongst many other, that are linked to the entirety of farms present and the spatial configuration that these farms have (Termorshuizen and Opdam, 2009). Following this approach, agricultural landscapes must be understood as the result of farming practices applied, as i) the farms are the critical level at which decisions are made in terms of management of natural resources, ii) climate, landforms and soils change at a much slower pace than the farming system, and iii) this understanding provides the foundation for the more quantitative analyses to be performed in the next stage of the work.

In this context, it is important to note that limitations exist in the design of AEZ(farm) typology, and that the modelling has a number of shortcomings. Although similar issues have been highlighted in the construction of EU typology (Andersen et al., 2007), the New Zealand farm typology is not able to categorise farms into groups with a homogenous performance in terms of farm management. In order to build an improved biophysical typology, more detailed input data than currently available is needed. Although a significant and positive correlation between areas (in ha) accounted by LENZ and AgriBase exists (Table 9), ideally more efforts should be invested in the validation of existing farm biophysical data to obtain an improved biophysical database that represents more precisely the full spectrum and spatial detail of the New Zealand farming environment.

Notwithstanding these limitations, about 90% of UAA and predominant farm types are captured (and spatially-referenced) in AgriBase, without the risk of over- or under-representation of smaller-sized farms, a reported weakness in the FADN database (Andersen, 2017), but with the admonition of potential overlaying issues. The database also allows for farm holdings size assessment (small, medium, large farm holdings), both within farm and AEZ typology. The farm types, clustering criteria and discerning threshold values used here, in accordance with TSARA threshold values, seem to be a good starting point, as they provide a basis for evaluation of environmental (and potentially socioeconomic) performance of farms across different sectors in New Zealand.

4. THE SUSTAINABLE DEVELOPMENT GOALS

4.1 Background

4.1.1 Development of the SDG

The Sustainable Development Goals (SDG) were an evolution from the previous Millennium Development Goals (**MDG**) (Griggs et al., 2013). The MDG were agreed in September 2000, and were a set of eight global goals for humanity with targets set for 2015. The global goals were:

1. Eradicate Extreme Hunger and Poverty
2. Achieve Universal Primary Education
3. Promote Gender Equality and Empower Women
4. Reduce Child Mortality
5. Improve Maternal Health
6. Combat HIV/AIDS, Malaria and other diseases
7. Ensure Environmental Sustainability
8. Develop a Global Partnership for Development.

Within the MDG, targets and indicators were established to track progress. As an example, some MDG and their related targets are provided below:

MDG	**Target**
Promote gender equality and empower women	Equal girls' enrolment in primary school
Improve Maternal Health	Reduce maternal mortality by three quarters
Ensure environmental sustainability	Halve proportion of population without improved drinking water

Progress and achievement on the MDG was in general very positive. While for some targets little progress was made, for most goals the targets were either achieved or close to achieved. The United Nations tracked progress on 16 sub-goals across 9 regions and sub-regions, and excellent progress or good progress was made in 102 out of 144 of the sub-goals by region (United Nations, Department of Economics and Social Affairs, 2015), *i.e.*, at least good progress was made across 71 per cent of the MDG by region.

As a result of the progress on the MDG, the international community agreed in 2015 to a new set of goals for 2030, which were the Sustainable Development Goals. The SDG are a set of 17 goals that extend and build on the progress made on the MDG (**Figure 7**).

Figure 7. The Sustainable Development Goals.

Each goal includes a set of targets to be achieved over the 15 year period from 2015 to 2030. For the targets, the UN Statistical Commission has developed a set of 230 indicators it will use to track and measure progress at a global level for many of them (UN Inter Agency and Expert Group on Sustainable Development Goal Indicators, 2016). However, at the national level, individual governments have responsibility for developing measures and indicators suitable for tracking their own progress towards SDG targets.

4.1.2 New Zealand's obligations regarding SDG

The SDG goals and targets are aspirational and are not binding on countries. Countries have committed to work towards achieving them in line with their own national circumstances. The indicators agreed by the UN Statistical Commission for SDG in 2016 cover all goals but not all targets. Where they apply, indicators from the final list of agreed SDG indicators can be used, or others developed if they are not so suitable in a particular country. For the targets that do not have any indicators however, it is up to each individual country to develop their own approach for deciding which indicators are most suitable for measuring progress towards the targets.

New Zealand has to set for itself how it will measure progress towards the SDG and the indicators it will use. Not all indicators will be equally applicable to all countries. New Zealand government officials are currently working through the process of deciding their approach to this question.

4.1.3 Use of SDG in TSARA

The wider TSARA project is working on developing different pathways to achieving the SDG. It aims to assist countries to meet their targets under the SDG by modelling the effects of different types of agriculture and matching that data with indicators of progress towards the SDG. The researchers hope to be able to forecast different pathways towards achieving the SDG using different mixes of land-use. In this way land-use change can be modelled to show its effect on different SDG and any trade-offs between SDG.

The research is focused on SDG goal 2 – to *End hunger, achieve food security and improved nutrition and promote sustainable agriculture*. In particular the research is focused on targets 2.4 and 2.5 as they relate to sustainable agriculture. SDG targets 2.4 and 2.5 are that:

- Target 2.4 – By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production, that help maintain ecosystems, that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters and that progressively improve land and soil quality.
- Target 2.5 – By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels, and promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge, as internationally agreed.

The UN Statistical Commission has developed three indicators for targets 2.4 and 2.5 (UN Inter Agency and Expert Group on Sustainable Development Goal Indicators, 2016) listed in **Table 10.**

Table 10. UN developed indicators for SDG targets 2.4 and 2.5.

SDG target	Target indicator
2.4	2.4.1 Proportion of agricultural area under productive and sustainable agriculture
2.5	2.5.1 Number of plant and animal genetic resources for food and agriculture secured in either medium or long-term conservation facilities
2.5	2.5.2 Proportion of local breeds classified as being at risk, not-at-risk or at unknown level of risk of extinction

4.1.4 Purpose of research

TSARA is a programme led by European research organisations and funded through a European international collaboration. One of the European Union’s strengths is its ability for its member states to cooperate and use trade and competitive advantage to achieve shared goals more effectively than if each country worked towards them individually. The European Union wishes to play to the strengths of its individual member states and trade off among them to cooperatively achieve the targets set under the SDG. This project aims to demonstrate how that process could work first by developing national transformational pathways to the SDG. Later an analysis of trade and international markets will be required to examine how variable progress on the SDG at a national level can be suitably aggregated at the transnational level.

TSARA will evaluate the trade-offs and synergies between increasing agricultural production and negative environmental outcomes such as impacts on air quality, water quality, GHG emissions and biodiversity. To do this, indicators for monitoring the sustainability of different farm types will be developed at study sites both within and outside Europe. New Zealand was chosen as one of the principal study sites outside Europe. New Zealand was chosen as a comparison in part to contrast the approach to measuring progress to the SDG as a non-EU trading partner and one without agricultural production subsidies.

The current research project focuses on the availability of the data required. To develop pathways and to track progress against those pathways, data must be available at the national level and the farm level of the impacts and trade-offs involved.

The project aims to develop indicators suitable for measuring progress in New Zealand towards targets 2.4 and 2.5, and establishing whether these indicators can be feasibly used for modelling pathways to achieving SDG. Feasibility is examined from the perspective both of whether the data is currently being collected or could be collected, and whether the data can be linked to different farm types to establish trade-offs.

4.1.5 UN-developed indicators

There are several considerations for identifying or developing good indicators for modelling pathways to the SDG. Indicators need to be:

- based on data that are feasibly available or collected
- meaningful about the SDG target they are representing
- precise and well defined
- represented in a data type that can be modelled at the farm level, which means that it must be amenable to quantification or categorisation.

The existing indicators developed by the UN Statistical Commission for targets 2.4 and 2.5 do not meet all of these criteria. Under indicator 2.4.1, ‘productive and sustainable agriculture’ is not defined, which leaves the overall indicator ambiguous and unable to be compared across regions or countries. Indicators 2.5.1 and 2.5.2 meet the first three criteria and are useful indicators at the national level, but are not related to farm practices. As a result they are not useful for modelling pathways towards achieving the SDG. In addition while indicators 2.5.1 and 2.5.2 are useful they are not sufficient, since they relate only to the preservation of genetic diversity, and do not cover other aspects of target 2.5 such as equitable sharing of the benefits of genetic diversity.

The project aims to expand on these indicators by testing the feasibility of using additional indicators suitable for measuring progress towards the SDG and whether these can be linked to farm typologies to model the effect of land use and land-use practices on achieving the SDG.

4.2 Stakeholder process

The TSARA programme is interested in identifying SDG indicators that will be useful for stakeholders in the government and private sector. On 29 March 2017, researchers held a workshop in Wellington, New Zealand, to get views from stakeholders on the UN SDG. The workshop focused in particular on targets 2.4 and 2.5 and how New Zealand might go about tracking its progress towards achieving these targets. People from a range of relevant organisations were invited to help to identify what the most suitable indicators were for each target. In attendance were representatives from central government (MfE, MPI, MFAT, Landcorp), agricultural industry bodies (Fonterra, Zespri, Federated Farmers, Business NZ, the Forest Owners Association), environmental non-governmental organisations (NGOs) (Ecologic, Forest and Bird) and research organisations (Lincoln University/AERU, AgResearch and GNS Science). Representatives from Māori organisations were expected but were prevented from attending by poor weather that closed the airport.

The workshop began with an introduction of the SDG, in particular SDG 2.4 and 2.5. These two SDG targets, which are described above in section 4.1.3, were broken down into five subcomponents:

- **2.4A** – By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production
- **2.4B** – By 2030, ensure sustainable food production systems and implement resilient agricultural practices that help maintain ecosystems and that progressively improve land and soil quality
- **2.4C** – By 2030, ensure sustainable food production systems and implement resilient agricultural practices that strengthen capacity for adaptation to climate change, extreme weather, drought, flooding and other disasters
- **2.5A** – By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed and domesticated animals and their related wild species, including through soundly managed and diversified seed and plant banks at the national, regional and international levels
- **2.5B** – By 2020 promote access to and fair and equitable sharing of benefits arising from the utilization of genetic resources and associated traditional knowledge.

Breaking the targets down into these component parts provides structure for examining the applicability and coverage of indicators to the targets. Throughout the rest of the report, references to 2.4A through to 2.5B are references to these components of each target.

The workshop was designed with a combination of participatory exercises and informational presentations. In the first workshop exercise, participants were asked to think about the five SDG components with a focus on what New Zealand. They were asked to describe what the country would look like in 2030 if these goals had been met and how we would know that they had been met. The next item was a presentation on the farm typology developed for the TSARA modelling, which was described above in section 3.2 of the report.

The next part of the workshop focused on indicators. To begin this segment and to get participants thinking clearly about useful indicators, the participants were provided a short presentation on the qualities of good indicators. The key characteristics good indicators discussed were that they are:

- clearly defined and standardised
- affordable to measure and have accessible data
- performance-based
- easily communicated and understood
- valid and meaningful.

The next activity was a small-group exercise in which participants brainstormed possible indicators for each of the five SDG components. After the indicators were identified, all the participants prioritised the indicators. There were two prioritisation exercises. In the first exercise, participants were asked to select the eight most important or useful indicators. The 'voting' by participants created a score for each indicator, with more votes leading to higher scores. In the second prioritisation exercise, participations were asked to identify their one most important indicator. The purpose of the second exercise was to reveal minority views among the different stakeholders. The final workshop activity was by a discussion of the indicators that participants chose and the advantages and disadvantages of each.

4.3 Results from the workshop

4.3.1 Summary of discussion

Workshop participants described what New Zealand would be like and how it would be different if each of the components of SDG targets 2.4 and 2.5 were met. The discussions are summarised below for each subcomponent.

2.4A – Increasing productivity and production

Participants focused largely on the idea that we will see an increase in the value of exports, arising from more efficient use of resources and better matching of land-use to different production types and regions.

2.4B – Maintaining ecosystems and improving soil

Participants focused on a spread of different aspects, with some stating that there would be measures put in place to minimise soil/land erosion using parameters to measure the soil quality. Others discussed the need for a regulatory framework that encourages better matching of land-use to land-type and targeting of limited resources to high-value areas. A greater focus on biodiversity, with an awareness that New Zealand pasture is very mono-cultural, would enhance the ecosystems.

2.4C – Strengthening adaptation

Different aspects of resilience were discussed, including:

- ensuring there is a range of species options available for agricultural use that are climate-

change resilient
- bringing climate change into infrastructure planning and a focus on the wider community and landscape, rather than just agriculture and farms.

Participants agreed that an important issues was how climate change impacts on agriculture go beyond the farm to essential transport links, impacts on processing facilities and community impacts too.

2.5A – Maintaining genetic diversity

Participants described picture of New Zealand where a variety of species are used in farms and forestry. This contrasts with the status quo where pasture farms rely predominantly on ryegrass and production forestry relies on *Pinus radiata*. Participants said that there is a regulatory hurdle to navigate as the Hazardous Substances and New Organisms Act prevents the introduction of greater species diversity and as a result no new species of agronomic value have been permitted to be introduced to NZ since 1998.

It was also discussed that seed banks may offer a solution as a range of organisms could be kept in plant banks or otherwise not introduced yet until deemed necessary.

2.5B – Promoting access to genetic resources

Participants struggled to articulate what this aspect looked like in New Zealand. Discussion focused on rejuvenated rural communities, with a younger and more diverse work force in the primary sector as well as having a greater share of economic benefits going back to the producers.

4.3.1 Results regarding indicators

Participants at the workshop developed a set of indicators for measuring progress towards the SDG targets 2.4 and 2.5 and ranked their importance and usefulness, relying on their personal and professional experience in the agriculture and environment sectors. The full list of indicators developed and their ranking by participants is listed in **Appendix 3**. The indicators they ranked the highest in each category are presented below.

2.4A – Increasing productivity and production

- Yield per unit of land area/input as a way to measure the efficiency of production
- An index of different products produced and exported to measure product diversification
- The value of food exports, taking into account the costs of production across the whole supply-chain
- The proportion of locally produced food that is consumed in NZ
- A measure of the shift in land owner priorities from production/capital gain toward ecological responsibility

2.4B – Maintaining ecosystems and improving soil

- Soil health metrics, such as soil carbon at various depths to measure the quality of soil used for agriculture and forestry
- An index to measure the increase (or decrease) in indigenous biodiversity in agricultural landscapes
- A set of parameters that measure the health/quality of various elements (water, air, soil) to

create an indicator of ecosystem health

- Measuring the change in land use, particularly from more intensive/less sustainable uses to more sustainable and suitable land uses
- A measure of water quality, such as sediment (nitrogen or phosphorus) kg per hectare per year above natural background

2.4C – Strengthening adaptation

- Quantification of production losses caused by extreme weather to track whether this is reducing
- Measure of the land area impacted by climate events
- An index that measures the diversity of land use within regions, to track an increase in diverse land use
- A way to quantify the vulnerability of production systems and infrastructure to projected risk events
- A measure of the sustainability of our food exports by creating a calorie/emission ratio of exported food basket

2.5A – Maintaining genetic diversity

- The percentage or number of indigenous species and other genetic material that is protected through the use of seed and plant banks internationally
- A metric that measures organism biodiversity, with a separate indicator for indigenous and introduced species
- The number or percentage of all species on endangered list, both in NZ and world wide
- An index that measures the diversity of food consumed in rural communities

2.5B – Promoting access to genetic resources

- Social licence perception/awareness
- The percentage of freshwater management zones with targets considering baseline traditional knowledge

Participants also chose their one most important indicator. The indicators selected by at least one participant are listed below:

- Yield per unit of land area/input as a way to measure the efficiency of production
- A measure of the shift in land owner priorities from production/capital gain toward ecological responsibility
- The value of food exports, taking into account the costs of production across the whole supply-chain
- The proportion of locally produced food that is consumed in NZ
- An index to measure the increase (or decrease) in indigenous biodiversity in agricultural landscapes
- Measuring the change in land use, particularly from more intensive/less sustainable uses to more sustainable and suitable land uses
- A measure of water quality, such as sediment (nitrogen or phosphorus) kg per hectare per year above natural background
- Measure of the land area impacted by climate events
- A way to quantify the vulnerability of production systems and infrastructure to projected risk events

- A measure of the sustainability of our food exports by creating a calorie/emission ratio of exported food basket
- Social licence perception/awareness.

All of the indicators that were voted as the most important were also among the top ranked. This shows that the indicators people felt most strongly about were also the indicators that the group generally agreed on. Thus, there was no evidence of strongly held minority views that were being overwhelmed by other stakeholders.

After the participants had placed their votes, discussion was opened up to any further points to add or any points that people disagreed with. A number of issues were raised and debated. Participants noted some inconsistencies with the global framework or between the global framework and the indicators developed. For example, they talked about how the indicator that measures the percentage of locally produced food consumed in New Zealand might not fit with the overall aim of the SDG to eliminate world hunger. New Zealand exports the vast majority of the food it produce and the share consumed in New Zealand is not so relevant to the country's ability to reduce hunger globally.

Another issue raised was a lack of alignment between the global goal to eliminate hunger and the target to increase production. At a global level, sufficient food is produced to feed everyone, so the relevant issue is not the level of production. On the contrary, an important part of world hunger concerns problems with the distribution of food.

The issue of genetic technologies and genetically modified foods (**GM**) led to disagreement among participants. One suggested indicator was the number of GM-free species/varieties. However, other participants took the position that genetic modification is a continuum from selective breeding to transgenics, so that all species will fall somewhere along this continuum.

Finally, participants noted that many of the possible indicators have no unit or form of measurement, and may need further clarification and definition before use.

4.4 Feasibility assessment of suggested indicators from the workshop

After the workshop, the research team assessed the indicators developed by the stakeholders. Indicators were assessed for their feasibility, considering both the collection of the data and the possibility of linking the indicator to the farm types presented earlier. The researchers judged the ease with which data could be accessed or collected, identified potential sources and considered potential difficulties. **Table 11** to **Table 15** present the results of this feasibility assessment.

The participants struggled to identify as many possible indicators for target 2.5 as for 2.4. Researchers similarly found it more difficult to judge the feasibility of indicators for 2.5. Many of these indicators may not be feasible, or are not useful for either the SDG or the TSARA work. For example, they may not be measurable at the farm scale and so may not link to farm type and future pathways.

Finally, **Table 16** summarises the indicators according to their feasibility and the effort required. The judgement on feasibility and effort focused primarily on whether relevant data are currently being collected in some form, and whether it would be possible to link the data to the farm typology and AEZ developed for TSARA modelling.

Table 11. *Feasibility analysis for indicators under target 2.4A.*

*2.4A By 2030, ensure sustainable food production systems and implement resilient agricultural practices that **increase productivity and production***	
Suggested indicator	**Feasibility**
Yield per unit of land area/input as a way to measure the efficiency of production	This indicator is feasible but will require work. There are existing models that can disaggregate this information down to region or farm type scale. Calibration of these models would be required, which would be difficult but is possible.
An index of different products produced and exported to measure product diversification	This is feasible, and could be done quite easily. Statistics New Zealand collects and reports high quality data on New Zealand exports, and differentiates food products based on harmonized system codes. This data is easy to find and would require little work to develop into an index.
The value of food exports, taking into account the costs of production across the whole supply-chain	This is probably feasible. This would require an input-output analysis of the food industry. Statistics New Zealand has data on both inputs and outputs, although this data may not be complete. While this is not technically difficult, it would require a lot of work, and may run into issues with incomplete data.
The proportion of locally produced food that is consumed in NZ	This may be feasible. Data for each different food type is likely to be collected and held by industry organisations, so would come from different sources and may not be consistent or easily comparable. The dairy industry collects data on production and export volumes, and local consumption can be calculated from the difference. Much of the grain produced in New Zealand is consumed locally. It is unclear what data is collected on this for the meat industries. Horticulture New Zealand has some data for the horticulture industry, but its quality or level of detail is unknown. In addition to feasibility issues, it may not be a useful measure of the SDG (based on participants' objections to this during the workshop), and not particularly relevant to the farm types.
A measure of the shift in land owner priorities from production/capital gain toward ecological responsibility	This is likely to be feasible. Landcare Research, with help from MPI, has conducted a survey of land owners, which, if it continues, could be useful. It collects information on the attitudes of land owners, and this data could be used to look for a shift in attitudes over time. Unfortunately, the response rate is very low, which may affect the survey's

	representativeness. However, the data could also allow researchers to develop indicators for land owners and then gather data more widely. The ability to compare results internationally would also need to be investigated.

Table 12. Feasibility analysis for indicators under target 2.4B.

*2.4B By 2030, ensure sustainable food production systems and implement resilient agricultural practices that **help maintain ecosystems and progressively improve land and soil quality***	
Suggested indicator	**Feasibility**
Soil health metrics, such as soil carbon at various depths, to measure the quality of soil used for agriculture and forestry	This is unlikely to be feasible. Soil carbon data is not available in a comparable way that will allow changes over time to be measured.
An index to measure the increase (or decrease) in indigenous biodiversity in agricultural landscapes	It is unclear whether indices exist for this indicator. Biodiversity indices do exist but are often not specific to agricultural landscapes. Further work would be required to assess whether existing indices could be adapted for this purpose.
A set of parameters that measure the health/quality of various elements (water, air, soil) to create an indicator of ecosystem health	This is not currently feasible, but could be in the future. Researchers Estelle Dominati and Alec MacKay at AgResearch are doing work on this, however it is still under development and there is no index for New Zealand.
Measuring the change in land use, particularly from more intensive/less sustainable uses to more sustainable and suitable land uses	This may be feasible. Sustainable land use is broad and difficult to measure, however intensive land use can be used as an indicator. Dairy NZ and Beef + Lamb have data on the land use intensity of their respective types of farming. While this data exists, it is likely to be commercially sensitive information for the organisations that collect it, and will require engagement with these organisations to be able to access it.
A measure of water quality, such as sediment, nitrogen, or phosphorus loss in kg per hectare per year above the natural background	This is a measure of water pollution from agriculture, and may be feasible. Nitrogen and phosphorus data can be developed based on models, though actual measurement is may not be occurring with sufficient granularity. The models can then be calibrated to actual data, but the number of actual data points relative to modelled points is likely to be low. In addition, the waterways that are most measured tend to be the ones that are considered the worst or most vulnerable, so there is sampling bias in the existing data. It is less feasible to use sediment as an indicator, as there is less data and less modelling available for this.

Table 13. Feasibility analysis for indicators under 2.4C.

*2.4C By 2030, ensure sustainable food production systems and implement resilient agricultural practices that **strengthen adaptation to climate change and extreme events***	
Suggested indicator	**Feasibility**
Quantification of production losses caused by extreme weather to track whether this is reducing	This is probably feasible. Production losses are reported after extreme weather events so it appears that this data is collected, possibly by MPI or insurance companies. We will need to check whether this data is available, however it may simply require collation and tracking of existing data. One issue to address concerns linking losses to land uses. For modelling purposes, we are interested in losses by type of land use. It is unknown whether the data are collected in a way that would allow that link to be made.
Measure of the land area impacted by climate events	This is feasible, though requires definition of some of the terms. The definitions of climate event and impacted land will need to be clarified in order to measure this. It is likely that data is available, as MetService keeps track of when and where climate events occur, and MPI will likely be able to provide data on the area that is affected. This can also be linked to farm typologies and agri-environmental zones.
An index that measures the diversity of land use within regions, to track an increase in diverse land use	This may be feasible. AgriBase could be useful for this, although there are limitations in its coverage and data quality is not always as good as desired, but data does exist on land use. Motu's LURNZ model is another possible source, but it is not clear whether the database continues to be updated.
A way to quantify the vulnerability of production systems and infrastructure to projected risk events	May be feasible in the future. There is not currently any measure on this, but there in a National Science Challenge on it (Resilience to Nature's Challenges). While there is not yet any output, it may be possible to work alongside this challenge.
A measure of the sustainability of our food exports by creating a calorie/emission ratio of exported food basket	This is feasible. MPI has data on emissions produced per unit of food by some food types. There is also some modelled data on this. This food type data could also be applied to the farm types, though it would require further work with MPI to develop data to a suitable level of detail for this purpose.

Table 14. Feasibility analysis for indicators under target 2.5A.

*2.5A By 2020, **maintain the genetic diversity of seeds, cultivated plants and farmed animals, including through soundly managed and diversified seed and plant banks at the regional, national and international levels***	
Suggested indicator	**Feasibility**
The percentage or number of indigenous species and other genetic material that is protected through the use of seed and plant banks internationally	This is probably feasible. However, it is not so useful for TSARA, as it measures at a national level rather than regional or farm type level.
A metric that measures organism biodiversity, with a separate indicator for indigenous and introduced species	This may not be feasible. It is unlikely that there is available data on biodiversity at a farm or region level.
The number or percentage of all species on endangered list, both in NZ and worldwide	This is unlikely to be feasible. There is data available on species on the endangered list, however it is aggregated at a national level, so separating out the effect of agriculture on endangered species or species loss is very difficult.
An index that measures the diversity of food consumed in rural communities	This may be feasible. Supermarkets or their marketing leads the market in rural communities as they are locally owned and operated. There are similar confidentiality and commercial sensitivity issues here to the land-use intensity data that will need to be approached carefully.

Table 15. Feasibility analysis for indicators under target 2.5B.

2.5B By 2020, ***promote access to, and fair and equitable sharing of, benefits arising from genetic resources and associated traditional knowledge***	
Suggested indicator	**Feasibility**
Social licence perception/awareness	This is potentially feasible. There is nothing that currently exists on this but it could be done. Ken Huey, Geoff Kerr and Ross Cullen report on perceptions on the environment every three years. It could be feasible to use their data or work with them to build it into their work.
The percentage of freshwater management zones with targets considering baseline traditional knowledge	This is possibly feasible. Regional councils usually publish their targets, so it may be possible to find data on this, though it would take some work to collate it across local and regional councils.

Table 16. Feasibility summary of New Zealand SDG indicators identified.

SDG target element	Feasible, small effort	Feasible, greater effort	Infeasible to collect or link to farm types
2.4A – Increasing productivity and production	Index of exports	Yield per unit area of land Value of food exports Locally produced food consumed in NZ Land owner priorities	
2.4B – Maintaining ecosystems and improving soil		Change in land use intensity Water quality	Soil health metrics Ecosystem health
2.4C – Strengthening adaptation	Land area impacted by climate events Calorie/emission ratio of exported food	Production losses caused by extreme weather Land use diversity	Vulnerability of infrastructure to risk events
2.5A – Maintaining genetic diversity		Diversity of food consumed in rural communities	Percentage of genetic material in plant banks Measure of organism biodiversity Species on endangered list
2.5B – Promoting access to genetic resources		Social licence perception/awareness Percentage of freshwater management zones with targets considering baseline traditional knowledge	

5. DISCUSSION

5.1 Similarities with TSARA indicators

5.1.1 Target 2.4

The wider TSARA project is considering a set of indicators to be used for modelling farm types and their contribution to pathways to achieving different SDG.

For 2.4, the kinds of indicators the EU TSARA project is exploring included aspects such as:

- Value of losses from natural disasters
- Efficiency of input resource use
- Efficiency of yield compared to the maximum attainable, referred to as the yield gap
- Emissions associated with agriculture

Some of the indicators suggested by New Zealand stakeholders for target 2.4 are similar to those being considered by the wider TSARA project. Both sets of indicators contains measure of productivity, that is, outputs per input or resource use. The New Zealand set included, for example, production per hectare, while the European set included efficiency of input use. Emissions from agriculture were also included in both sets of indicators, although the New Zealand stakeholders were particularly interested in emissions as a ratio with calories exported.

The value of losses from natural disasters is similar to the indicator of production losses from extreme events. Both indicators assess the economic value of losses as a measure of resilience to climate change and extreme events. The New Zealand indicator focuses more on agricultural production losses while the TSARA indicator looks wider at all losses including lives lost. The New Zealand indicator is focusing on agriculture as SDG 2 ties together agricultural practices that promote resilience to climate change and extreme weather for the purpose of improving production and productivity in order to end hunger and malnutrition. In this sense, while wider losses from climate change and extreme events will be relevant to the SDG, target 2.4 is particularly focused on the loss as it relates to agricultural production.

5.1.2 Target 2.5

For SDG target 2.5, the EU TSARA project is considering indicators of activities that promote genetic diversity or traditional knowledge such as the ratio of agricultural extension workers to farmers, or the share of calories consumed from non-staple crops. It is also considering other metrics such as the share of renewable energy derived from agriculture and forestry.

The New Zealand-based indicators developed in the workshop are somewhat similar. The diversity of food consumed in rural communities is similar in intent to the indicator for the share of calories from non-staple crops. Both indicators are looking at a measure of consumed food diversity (i.e. how monocultural the food consumed by farming communities is), and whether the benefits of genetic diversity are flowing through to those communities.

5.2 Differences with TSARA indicators

5.2.1 Target 2.4

In New Zealand, indicators for target 2.4 relate less to efficiency and more to impacts of agriculture on the landscape. For example, the potential TSARA indicators include indicators based on the efficiency of fertiliser input or the yield as a proportion of maximum attainable yield, while in New Zealand the proposed indicators focused more on measures of water quality or farming intensity. This reflects the national conversation that has been occurring over the last 10 years on the role of intensifying agriculture in New Zealand's economy and the impacts it has on land and water quality. New Zealand's livestock farming systems are predominantly pasture based, and intensification over the last decade has resulted in negative impacts to water quality (Parliamentary Commissioner for the Environment, 2015). This has given rise to questions and public debate about intensification as environmental values form part of New Zealanders' cultural identity (Department of Conservation, 2014).

The other potential reason for the difference could be the policy environment. Since 1991, New Zealand's planning legislation, the Resource Management Act, has focused on impacts and effects that are permitted or restricted, rather than activities that are permitted or restricted. At the time, the approach was revolutionary in being agnostic on activities that were permitted or not permitted and simply prescribing the environmental effects one was prohibited from inducing without further permitting and licensing. This approach overturned dozens of pieces of legislation that had required permits for particular types of activities. This approach contrasts with Europe's more generally prescriptive approach as a civil law jurisdiction. In civil law jurisdictions, laws are completely codified, as opposed to common law jurisdictions where much of the law is contained in precedent but not listed in a statute (University of California at Berkeley, 2010). This approach to environmental regulation was likely an influence on how New Zealand policymakers, including those attending the workshop, approach questions on measurement and indicators. The New Zealand indicators being more outcome based than process based than the EU indicators is therefore unsurprising.

One area where this approach is clearly not occurring however is GHG. Agricultural emissions comprised 48 per cent of New Zealand's GHG emissions in 2015 (MfE, 2017). The TSARA project included an indicative indicator of the proportion of agriculture in its greenhouse gas profile and the absolute amount of greenhouse gas emissions from the agriculture sector. In this, the TSARA researchers are using an outcome based approach rather than an activity based one. The New Zealand workshop participants did not include greenhouse gas emissions alone as an indicator for target 2.4. Instead, they focused on the emissions per calorie produced, which shifted the discussion to one of efficiency and productivity rather than absolute levels of emissions.

There is potentially some discussion around whether agricultural greenhouse gas emissions are a direct measure of any of the three aspects of target 2.4, which are increasing productivity and production, maintaining ecosystems and improving soils and improving resilience to extreme events. One way to include greenhouse gases in 2.4 is to consider them part of maintaining ecosystems and improving soils, since climate change contributes to degraded ecosystems and desertification. However, emissions and impacts are not linked locally, which moves the focus away from the farm scale or the regional scale.

5.2.2 Target 2.5

The EU-based researchers are considering metrics for target 2.5, including the ratio of agricultural extension workers to farmers and the amount of energy crops being produced from agriculture and forestry. The ratio of agricultural extension workers is less relevant in New Zealand because it is a developed country with a technologically advanced agricultural sector. In addition, the sector does not rely on extension agents from government agencies or research centres; instead, much of the knowledge transfer relies on private agents. Thus, the indicators identified might need to consider the economic and regulatory environment of each country.

The share of renewable fuels derived from agriculture and forestry appears to be being used as an indicator of the benefits of genetic diversity and traditional knowledge. The TSARA researchers are using it as an indicator of wider participation in the benefits of genetic information. This example appears to be too specific to be a useful indicator for New Zealand. The climate is not particularly suitable for energy crops aside from forestry, and the share of forestry being used in renewable fuels is not indicative of a sharing of technological benefits but of the relative costs of different technologies and the organisation of markets. The New Zealand Government has a programme to promote the use of wood as an energy source (Energy Efficiency and Conservation Authority, 2017). However a recent review made the observation that wood energy is not economically beneficial compared to fossil fuel alternatives (Energy Efficiency and Conservation Authority, 2016).

New Zealand indicators developed to address target 2.5 focused mainly on the biodiversity of agronomic species, and the number of critically endangered species. It also included indicator on the use of traditional knowledge. Traditional knowledge has the potential to be more significant a factor in New Zealand where the indigenous tangata whenua (Māori people) are a significant part of the national population and control an important proportion of the primary sector resources. Tikanga Māori (Māori traditional knowledge, practices and perspectives) is increasingly being incorporated into freshwater management in New Zealand through co-governance and co-management approaches (Harmsworth, 2016).

5.3 Coverage of Sustainable Development Goals

Table 16 shows that each of the key components of SDG targets 2.4 and 2.5 has at least one indicator associated with it that is likely to be feasible to collect and link to farm types. Drilling into these sub-targets, each of the aspects of target 2.4 appears to be well represented by its indicators. For example, the trend in production losses associated with extreme events appears to be a fair representation of whether New Zealand agriculture is strengthening its adaptation to climate change and extreme events. Target 2.5 appears to be less comprehensively covered. For target 2.5A, the diversity of food consumed in rural communities is relevant to the overall genetic diversity available to New Zealand agriculture, but only indirectly. Particularly given that the vast bulk of food produced in New Zealand is exported, food consumed and food produced may not be particularly related.

Target 2.5B, the equitable access to and benefit from the use of genetic resources and traditional knowledge, is not very well covered by indicators. One additional indicator that could be considered is the relative yield of Māori vs non-Māori farms as a measure of equitable access to the benefits of genetic information and traditional knowledge. This could be measured as the yield gap between Māori farms and the national average. Research commissioned by the Ministry for Primary Industries (PwC, 2013) identified Māori land parcels and evaluated the relative yield of Māori Freehold Land as compared to non-Māori land. The project demonstrated that it was clearly possible to collect information on this indicator and relate it back to identified farm-types.

5.4 Overall feasibility

The research has demonstrated that it is feasible to develop indicators for tracking progress towards SDG targets 2.4 and 2.5 and to link those indicators to a representative set of farm types. Sufficient data on agricultural activity exists to develop a farm typology that makes sensible distinctions in the New Zealand context. In particular, existing classifications from industry bodies – including data on profitability as a measure of intensity – can be matched to data on the location of different agricultural activity.

The farm typology for New Zealand broadly matches the farm typology developed for Europe in the TSARA project. TSARA's typology relies on four key variables:

- Size
- Intensity
- Specialization
- Land-use.

In New Zealand the typology of farms relies principally on land-use and specialization. Intensity as measured using net revenue per hectare by TSARA is not a particularly distinguishing feature in the New Zealand typology as most sub-types within a farm type have the same category of intensity. The data sources used to categorize agricultural activity in New Zealand also provide data on intensity in a comparable way to the TSARA typology so this can be included in future modelling if necessary.

TSARA AEZ use a combination of environmental zone (including climate, slope and elevation) and soil C based on the OCTOP database. For New Zealand, AEZ use a similar classification of zone based on climate, topography and soil health. Soil C is not one of the measures of soil health included in the New Zealand classification as the data quality on soil C stocks is poor, and not sufficient to be a useful variable.

In general, data exists or is being collected on a set of indicators that can be used to track New Zealand's progress towards SDG targets 2.4 and 2.5 and at least some of these indicators can be represented at the scale of farm types.

There are however limitations in the feasibility of using the indicators developed to track progress towards SDG targets 2.4 and 2.5. Some of the indicators – such as number of species in seed banks – are useful at a national level, but cannot be easily linked to different farm types in order to model pathways. In addition, SDG target 2.4 is more precisely defined than target 2.5, and several key concepts within target 2.5 need further unpacking. In particular the 'equitable sharing of benefits' derived from genetic diversity and traditional knowledge raises questions concerning the people affected and the benefits included.

Further work will be required to agree on the most useful indicators and collate the data in a form that is useful for modelling.

6. SUMMARY

6.1 Purpose of TSARA

The TSARA research programme is exploring the means to support and develop pathways to achieving the UN SDG targets. It is doing this by:

- classifying EU agricultural land-use and management into major types
- developing indicators for achieving the SDG targets that can be mapped to farm types
- modelling pathways to achieving the SDG targets through a backcasting approach
- engaging with societal actors on concerns and issues in the pathways developed.

The goal is to describe pathways using a backcasting approach in order to understand how to achieve the SDG and the trade-offs that might be required to do so.

6.2 Purpose of New Zealand work under TSARA

TSARA is mainly a European research project. The modelling and analysis will be informed principally by European data and will support the development of pathways towards the SDG as defined by those countries. To ensure that the pathways and models developed have wider applicability beyond the European context, several case studies are also being done to assess the feasibility of the approach. New Zealand was chosen as one such case study as an example of an agricultural trading partner to the European

Union. In addition, the absence of agricultural subsidies meant that New Zealand provided a greater contrast of regulatory environments to understand whether the approach was broadly applicable.

The key purpose of the New Zealand research then was to establish whether it is feasible to:

- develop a typology of farms and AEZ that is analogous to that developed for the European TSARA project
- develop useful indicators for tracking progress towards SDG targets 2.4 and 2.5
- link the farm types and the indicators together in a way that is comparable to that in the European project and can be used in the TSARA model.

6.3 Feasibility of providing New Zealand data for modelling

The research reported here was focused on assessing the viability of the New Zealand contribution to TSARA. The project demonstrated that it is feasible to provide a New Zealand typology of farms for modelling purposes. Agricultural activity in New Zealand was divided into 15 types. Data on the land in each farm type is available from a variety of sources – principally AgriBase, LINZ, Beef+LambNZ and DairyNZ. A classification of agri-environmental zones already exists for New Zealand, classifying areas in the main three islands of New Zealand according to their agricultural potential by climate, slope and soil characteristics.

The typology of farms and AEZ developed for New Zealand is however different from the typology developed for Europe. While many of the variables are similar, they are not the same. They are similar in structure however and so can be modelled together, but this modelling will need to account for differences in the underlying typology.

Of the indicators developed here, at least one for each aspect of targets 2.4 and 2.5 can be linked to the farm types to distinguish the impacts of different farm types on progress towards the SDG. It is unclear though, how comparable these indicators are with the indicators in the EU TSARA project. The EU researchers are still in the process of developing indicators for their model. This paper compares indicators developed for New Zealand with some of indicative indicators EU TSARA is considering, but full set of indicators has not yet been developed for EU TSARA.

6.4 Feasibility of linking to SDG

This research showed that it is feasible to develop indicators for progress towards the SDG that are relevant at the farm type scale. The research produced a set of indicators for measuring New Zealand’s progress towards SDG targets 2.4 and 2.5. Of those, the indicators that are feasible to collect and to relate back to the farm typology cover each of the five aspects of 2.4 and 2.5.

The indicators identified have support from relevant policymakers in New Zealand due to the process that generated them. Major policy agencies, non-government organisations and scientists from New Zealand were all part of the process of generating the indicators. Indicators were generated solely by this group of policymakers and stakeholders, and the indicators used here are the ones those stakeholders selected as the most important and valuable in each category.

One of the drawbacks to this process, as opposed to selecting or generating some indicators from the literature is that some of the indicators developed by the group were not entirely feasible to collect or to link to the SDG. While each aspect of the SDG is covered by at least one indicator that is feasible to collect and link to the farm typology, a larger number of indicators would be useful.

6.5 Next steps

This report concerns the first step of the New Zealand contribution to TSARA, which focused on identifying the data for WP1 and WP2. That work has been successful. The next steps are to engage with the modellers and data analysts in the TSARA programme to obtain more specifics on the data fields in the model and the requirements for parameterising the model. With that information, researchers will be able to assemble the data sets required and populate the model, in anticipation of developing the pathways. These next steps are already under way, including planning for two visits by European TSARA researchers in the next six to eight months.

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Appendix 1. Farm type code and description in AgriBase™

Farm type code	Description
ALA	Alpaca and/or Llama Breeding
API	Beekeeping and hives
ARA	Arable cropping or seed production
BEF	Beef cattle farming
DAI	Dairy cattle farming
DEE	Deer farming
DOG	Dogs
DRY	Dairy dry stock
EMU	Emu bird farming
FIS	Fish, Marine fish farming, hatcheries
FLO	Flowers
FOR	Forestry
FRU	Fruit growing
GOA	Goat farming
GRA	Grazing other people's stock
HOR	Horse farming and breeding
LIF	Lifestyle block
MTW	Meat slaughter premises
NAT	Native Bush
NEW	New Record - Unconfirmed Farm Type
NOF	Not farmed (i.e. idle land or non-farm use)
NUR	Plant Nurseries
OAN	Other livestock (not covered by other types)
OPL	Other planted types (not covered by other types)
OST	Ostrich bird farming
OTH	Enterprises not covered by other classifications
PIG	Pig farming
POU	Poultry farming
SHP	Sheep farming
SNB	Mixed Sheep and Beef farming
SLY	Saleyards
TOU	Tourism (i.e. camping ground, motel)
UNS	Unspecified (i.e. farmer did not provide indication)
VEG	Vegetable growing
VIT	Viticulture, grape growing and wine
ZOO	Zoological gardens

Appendix 2. Field names and number of subclasses aggregated in AgriBase™

Field name (class)	No. subclasses aggregated	Description
AAA_HA	1	Land area devoted to livestock
ARA_HA	12	Arable Land
BEF_Nos	9	Beef cattle numbers
BERR_HA	1	Berry fruit
BISO_Nos	1	Bison numbers
CAM_Nos	2	Camelids (Alpacas and Llamas)
CITR_HA	1	Citrus fruit
DAI_Nos	5	Dairy Cattle numbers
DEE_Nos	7	Deer numbers
DOG_Nos	1	Dogs
DONK_Nos	1	Donkeys
DUCK_Nos	1	Ducks
EMU_Nos	1	Emus
FLOW_HA	1	Flowers
FODD_HA	3	Fodder
FOR_HA	12	Forestry
FRUU_HA	1	Undefined Fruit
GOAT_Nos	1	Goats farmed
GRAZ_HA	1	Grazing Other Peoples Stock
HERB_HA	1	Herbs/Medicinal Plants
HORS_Nos	5	Horse numbers
KIWF_HA	3	Kiwifruit Orchards
NAT_HA	1	Native Bush
NURS_HA	1	Nursery
NUTS_HA	1	Nuts
OANM_Nos	1	Other Animals
OFRU_HA	13	Other Fruit
OLAN_HA	3	Other Land Use
OSTR_Nos	1	Ostrich numbers
OTH_HA	2	Idle land or planned for redevelopment
PIGS_Nos	4	Pig numbers
PIPF_HA	4	Pipfruit
POU_Nos	4	Poultry birds
SHP_Nos	9	Sheep numbers
STON_HA	6	Stone Fruit
VEG_HA	54	Vegetable Growing
VITI_HA	1	Viticulture

Appendix 3. Full list of suggested indicators.

The following tables list all the indicators that were suggested during the workshop for each component of the SDG, with the number of votes each indicator received.

Suggested indicator	Votes
By 2030, ensure sustainable food production systems and implement resilient agricultural practices that increase productivity and production	
Production efficiency – yields vs land area/inputs	7
Product diversification	6
Value of exports – full life cycle costs	5
Locally produced food – percent consumed in NZ	5
Environmental costs taken into economic/production accounting	3
Export of sustainable agri-tech and systems	3
Measure shift in land owner norms from volume production and capital gain toward ecological responsibility/stewardship/resilience/sustainable livelihood	3
Value to volume ratio	2
Life cycle emissions intensity (including freight)	2
Amount of available food energy per person (amount, or percentage increase)	2
Contribution to economy	1
Reduction of tariffs on food trade	1
Energy input/energy output (availability to consumer) measure for food produce	1
Level of production subsidies	1
Measurement of changed dietary norms toward consumption of low-emission foods, defined using whole life-cycle measurement (necessary for equitable global sharing of needed changes)	1
Production per hectare of land use	1

By 2030, ensure sustainable food production systems and implement resilient agricultural practices that help maintain ecosystems and progressively improve land and soil quality	
Indigenous biodiversity in agricultural landscapes is increasing	8
Ecosystem health indication	6
Soil carbon at depths 2, 30, 100 cm	5
Soil health metrics defined, measured, reported	4
Land use change	4
Sediment kg per hectare per year above natural background	4
Nitrogen kg per hectare per year	3
Ecosystem services measures – soil and climate	2
Soil quality, land care soil quality kit, regional council soil quality monitoring	2
Phosphorus kg per hectare per year	1

By 2030, ensure sustainable food production systems and implement resilient agricultural practices that strengthen adaptation to climate change and extreme events	
Reduction in production losses caused by extreme weather	6
Land area impacted	6
Increased diversity of land use within regions	6
Productivity and infrastructure vulnerability to projected risk events	5
Calorie/emission ratio of exported food basket	3
Resilience design tools used for key infrastructure projects	2
Repair cost to infrastructure	2
Increase geographical spread of production systems, spread distance and spread risk	1
Disruption days following climate events	1

By 2020, maintain the genetic diversity of seeds, cultivated plants and farmed animals, including through soundly managed and diversified seed and plant banks at the regional, national and international levels	
Significant increase in number of indigenous species, genetic material that is protected internationally	5
Separate indicator for indigenous and introduced organism biodiversity	4
Number of all species on endangered list	3
Diversity index for food consumed in rural communities	2
Number of new uses of indigenous species used in production	1
Percent of national coverage	1

By 2020, promote access to, and fair and equitable sharing of, benefits arising from genetic resources and associated traditional knowledge	
Social licence perception/awareness	10
Percent freshwater management zones with targets considering baseline traditional knowledge	4
Share of percent of renewable energy	1
Smell	1
Air pollution	1