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Irrigation REPORT

NATIONAL IRRIGATED LAND SPATIAL DATASET 2020 Update

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EXECUTIVE SUMMARY

This report documents the methodology and key results related to the update of national irrigated land dataset. The spatial data covers all mainland regions of New Zealand, with the exception of Nelson, which is not believed to contain significant irrigated areas.

The spatial dataset is an update of the national dataset that was first created in 2017. The current update has incorporated data from the 2019 – 2020 irrigation season.

The methodology that we have used to update the irrigated land dataset incorporates multiple lines of evidence, combined with expert judgement. We have integrated a number of sources of spatial data, including aerial and satellite imagery, and a national dataset of resource consents for water takes.

The total mapped areas have been compared to the 2017 Agricultural Production Statistics. This provides a partial benchmark of the dataset, but cannot be relied on completely due to the time-lag between the two datasets, and the difference in methodologies.

The updated spatial dataset gives a total of 903,465 ha. This is an increase of 109,022 ha from the 2017 spatial dataset. While some of this difference is accounted for by new irrigation development in the 2017 – 2020 period, we believe that it is partly due to other factors such as time-lags in the input datasets (particularly those used for the 2017 project), and improvements in the resolution and availability of aerial photos and multispectral satellite images.

A summary of the area mapped in each region is shown in Table 1, with the estimated uncertainty range. The uncertainty was estimated based on the ease of identifying different irrigation systems, with regional adjustments.

Table 1: Summary of 2020 mapped irrigated area by region, with estimated uncertainty

Region	2020 Mapped irrigated area (ha)	% of total mapped area	Uncertainty (± ha)
Auckland	9,938	1.1%	1,587
Bay of Plenty	13,072	1.4%	1,605
Canterbury	546,205	60.5%	21,583
Gisborne	9,667	1.1%	987
Greater Wellington	21,487	2.4%	2,014
Hawkes Bay	43,473	4.8%	3,592
Manawatu-Wanganui	27,480	3.0%	2,475
Marlborough	35,351	3.9%	1,808
Northland	12,337	1.4%	1,761
Otago	111,082	12.3%	5,771
Southland	22,254	2.5%	2,145
Taranaki	4,567	0.5%	655
Tasman	15,808	1.7%	2,015
Waikato	26,307	2.9%	3,943
West Coast	4,437	0.5%	647
Total (ha)	**903,465**	**100%**	**52,590**

Users of the spatial dataset are advised:

- This is a desktop study, and the methods used in the mapping cannot be relied on to give complete accuracy. Verification has only been carried out in a limited number of catchments, for other projects.
- Before reliance is made on the spatial dataset in relation to specific catchments, irrigation schemes or farms, it is recommended that updated information should be sought from irrigation schemes and / or individual farms.

1 INTRODUCTION

This report summarises the methodology and key results of the 2020 update to the national irrigated land spatial dataset.

The original national dataset was created in 2017, and incorporated mapping of irrigated areas in Canterbury that was completed in 2016.

In the context of this report, "irrigated land" means land that is equipped for irrigation. In some cases, whether irrigation actually occurs in any given summer depends on the climate, and whether irrigation land was irrigated at the time an aerial photo or satellite image was taken can depend on crop growth stage. As this update was able to use data from early 2020, when many parts of New Zealand were experiencing very dry conditions, we believe that there will be a strong correlation between areas equipped for irrigation and land actually being irrigated.

Since the original dataset was created, there have been a number of irrigation scheme developments, as well as developments on individual farms, and conversions from one irrigation system type to another. In addition, the availability and quality of the input datasets required to map irrigated areas have improved. Therefore, differences between the 2017 and 2020 datasets are not solely explained by an increase in actual irrigated area.

The spatial dataset has been provided to MfE as an electronic file.

2 METHDODOLOGY

2.1 Summary of approach used

The methodology that we have used to update the irrigated land dataset uses multiple lines of evidence, combined with expert judgement. We have integrated a number of sources of spatial data, including aerial and satellite imagery, and a national dataset of resource consents for water takes. The input datasets are discussed in more detail in the following sections.

The dataset is an update of the 2017 irrigated land dataset (Dark et al, 2017): it is not a completely new dataset. The approach to identifying and prioritising areas to update is discussed in Section 2.4.

The methodology for mapping irrigated areas involved the following steps:

1. **Farm boundary extents.**

   The extent of farm boundaries were mapped using land ownership and title data from LINZ.

2. **Irrigation systems clearly visible from aerial imagery.**

   Wherever possible, irrigated land was mapped based on the irrigation systems viewed from high-resolution (preferably 0.5 m pixel or less) aerial or satellite photos (Google Earth). The system type was determined by considering a range of factors including visual sighting of travelling irrigators, and markings on the ground, such as wheel tracks or irrigation patterns. If more than one set of images were available, a cross-reference was made between the imagery. In regions where there is a strong contrast between irrigated and non-irrigated land, this process typically identifies about 80-90% of the irrigated area with a high degree of accuracy.

3. **Resource consent data**.

   The farm boundaries layer (step 1) was combined with land slope and resource consent data (surface-water takes, ground water takes, and irrigation scheme command areas). This process identified farms and areas with resource consents to take water for irrigation. Such areas with land slope less than 15° were considered to be potentially irrigated. A spatial dataset of active water take consents for all regions was available; this was updated by NIWA for MfE in 2018. This dataset included attributes such as water source, use type, maximum rate and annual volume.

4. **Multispectral satellite analysis.**

   GIS layers of normalised difference vegetation index (NDVI) imagery were created from Sentinel-2 imagery, covering dry summer months from January to March. A strong contrast between the NDVI values for dry and actively growing vegetation indicates areas that are likely to be irrigated. As discussed below, this method is more successful in some regions than in others.

5. **Combine irrigation consent and NDVI analysis.**

   We combined the results from steps (3) and (4) to map irrigated areas that could not be identified in step (2). We manually mapped these areas, giving consideration to irrigation design and farm boundary limitations.

   In regions where there was not a strong contrast between irrigated and non-irrigated land in the aerial images and NDVI data, judgement was applied based on the available data sources to determine the area that was likely to be irrigated. As discussed in more detail below, the mapping accuracy in these regions was variable, and is generally expected to be lower than the regions with high contrast.

2.2 Input datasets

2.2.1 Land parcel boundaries

The NZ Property Titles Including Owners[1] was obtained from the LINZ Data Service. It was necessary to consider ownership information, rather than property boundaries alone, to account for situations where adjoining land parcels may have the same owner and water from a single resource consent is spread across multiple parcels.

2.2.2 Aerial photographs

Recent high-resolution aerial images were obtained from the LINZ data service[2]. The image dates for each region are summarised in Section 5.

During the project the LINZ 2020 basemap service[3] was launched. The API for this service was used to integrate the basemap data into the GIS maps used for irrigated area mapping.

In addition, particularly in regions where the aerial photography was less up-to-date, Google Earth imagery was used.

2.2.3 Multi-spectral satellite imagery

Data from the Sentinel-2 satellite multi-spectral instrument (MSI) was downloaded from the USGS EarthExplorer website[4].

Sentinel-2 images are recorded approximately every 10 days, and have a 10 m resolution. The spatial resolution is a significant improvement on the Landsat data that was used in the 2017 project, which had a 30 m pixel size.

Because many areas of New Zealand experienced drought, or drier than average, conditions in early 2020, this was an opportune time to update the NDVI data. The exception to this was Southland, which experienced some very wet weather and flooding in early 2020. For Southland, 2018 data was used; Southland experienced a drought in 2018.

Images within the target date range (January – April 2018 for Southland; January – April 2020 for all other areas) were filtered to exclude any images with more than 30% cloud cover, and images covering all of the potentially irrigable land within each region were selected. To achieve a coverage of each region with minimal cloud cover it was typically necessary to use images from a number of different dates.

The relevant bands from the Sentinel-2 images were merged together into a coverage for each regions, and NDVI values were calculated for each image pixel (see Appendix A).

To use the NDVI data to assist with mapping, the GIS layers were colour symbolised by NDVI value ranges: an NDVI of greater than 0.4 was considered highly likely to be irrigated when surrounded by land with much lower NDVI values.

Note that actively-growing vegetation will return a high NDVI value regardless of whether it is irrigated or not: native bush and other drought-tolerant vegetation will appear similar to irrigated land in an NDVI coverage. Interpretation of the NDVI data requires consideration of the contrast between irrigated and non-irrigated land.

An example of NDVI data highlighting irrigated areas in Canterbury is shown in Figure 1. The blue areas that show the extent of each centre pivot irrigator have $NDVI>0.4$; possibly-irrigated areas with $0.3<NDVI<0.4$ are shown in green; dryland areas with $0<NDVI<0.3$ are shown in yellow; open water

[1] https://data.linz.govt.nz/layer/50805-nz-property-titles-including-owners/
[2] https://data.linz.govt.nz/set/4702-nz-aerial-imagery/
[3] https://basemaps.linz.govt.nz/
[4] https://earthexplorer.usgs.gov/

(rivers and ponds) with NDVI<0 is shown in orange. If areas with low NDVI values were clearly irrigated at other times based on other evidence (e.g. sectors of a pivot that were cultivated at the time the multispectral image was taken), they were mapped as irrigated.

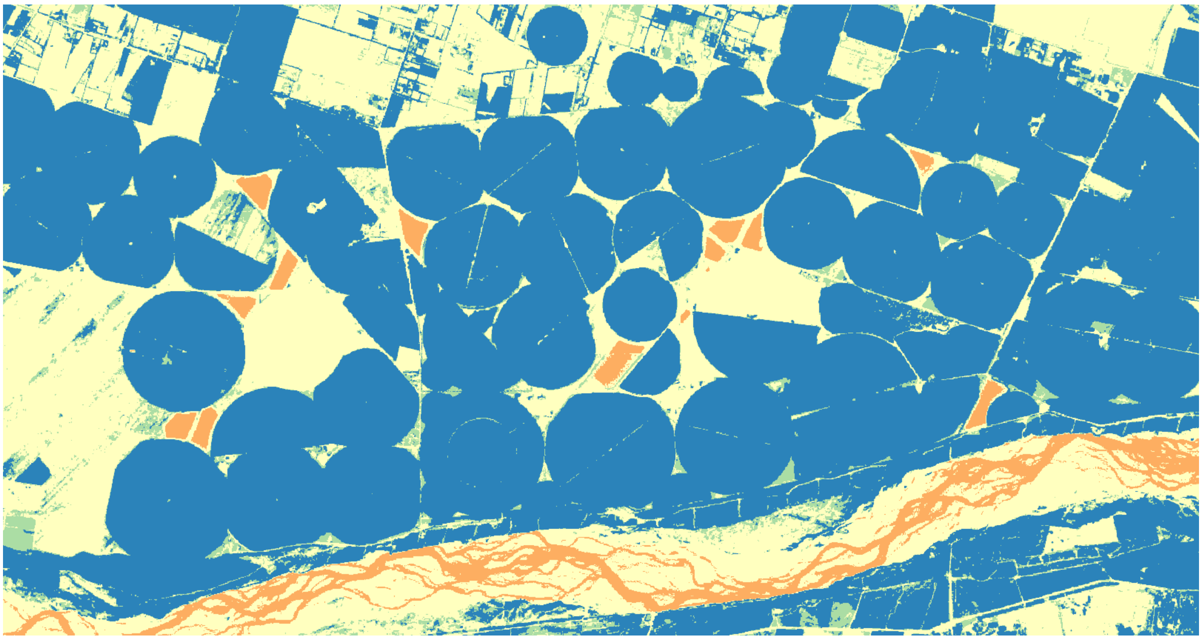

Figure 1: Example of NDVI, Canterbury.

A further example is shown in Figure 2: this shows an orchard area in Northland, with NDVI data overlaid on an aerial photo. The NDVI data clearly shows the orchard blocks, and shows that further development has taken place since the date of the aerial image.

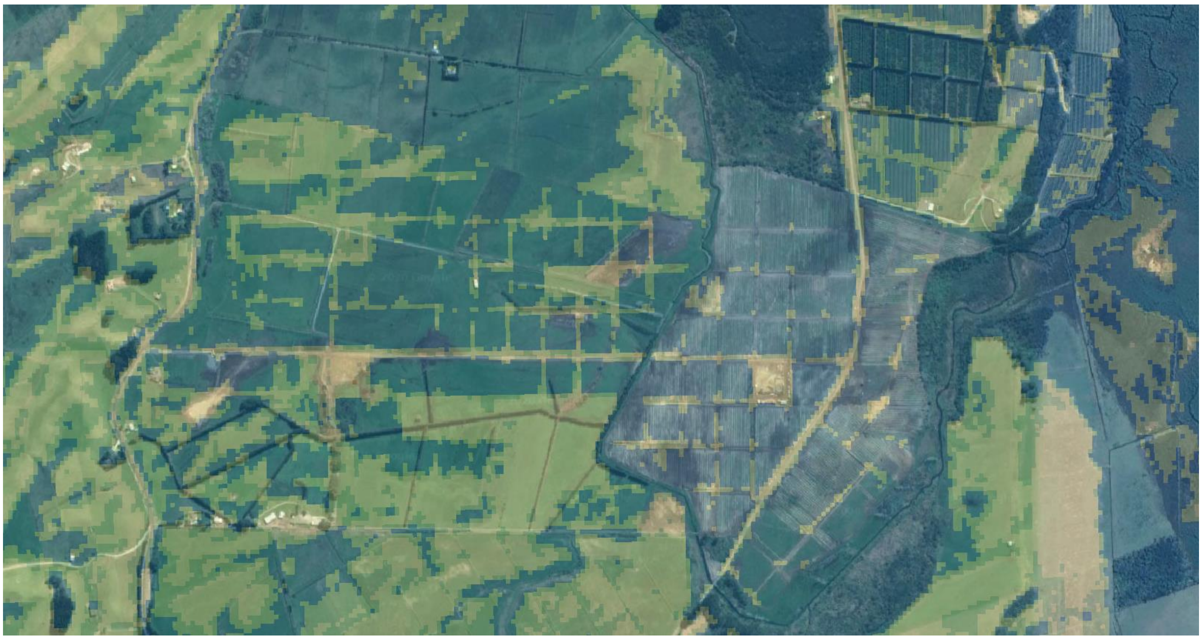

Figure 2: Example of NDVI overlaid on an aerial image, Northland.

The contrast between irrigated and non-irrigated land in the NDVI data varies between regions. The accuracy of the irrigated area spatial dataset is expected to be highest in Canterbury, Marlborough and Otago, where the contrast between irrigated and non-irrigated land, both in the NDVI dataset, and in the aerial imagery, is highest. In regions with a low NDVI contrast the accuracy is expected to be lowest. For this project the regions have been categorised as high, medium, and low NDVI contrast, as shown in Table 2.

As the level of NDVI contrast is related to the climate of the region, and therefore the need for irrigation in that region, the low-NDVI regions are those containing the smallest proportion of the total irrigated area. Therefore, on a national scale, we consider that the majority of the irrigated area has been mapped with high accuracy.

As this update has been completed following a very dry summer, during which many of the low NDVI contrast areas have been in drought conditions, the NDVI contrast has been less of a constraint on mapping accuracy than in the 2017 project.

Table 2: NDVI contrast categories by region

Regions	NDVI contrast
Canterbury	High
Marlborough	
Otago	
Gisborne	Medium
Hawke's Bay	
Manawatu-Wanganui	
Southland	
Greater Wellington	
Auckland	Low
Bay of Plenty	
Northland	
Taranaki	
Tasman	
West Coast	
Waikato	

2.2.4 Resource consents

A national water take consent database, compiled by NIWA in 2019 from Regional Councils' databases, and representative of resource consents in 2018 was used. This replaced the equivalent 2013 dataset that was used in the 2017 project.

This dataset was filtered for any consents where the "use" column referred to irrigation – i.e. consents with multiple uses where irrigation was not the primary use were still considered.

The dataset was further filtered by commencement date to isolate consents granted since February 2014 (the most recent date considered in the 2013 dataset). This subset of recently-granted consents was used as part of the prioritisation process for the update (see Section 2.4).

2.2.5 Land use

Land use data from LCDB5[5] was added as a layer in the maps that we worked with, but was not relied on heavily in the mapping process.

2.3 Region-specific datasets

Two region-specific datasets were incorporated into the updated dataset:

- A vineyards layer provided by Marlborough District Council.
- A field-verified irrigated area layer for the Manuherikia catchment, produced by Aqualinc for Otago Regional Council in 2018. The verification method for irrigated areas in this catchment was included in the "notes" field of the national dataset. The ORC layer was not

[5] https://lris.scinfo.org.nz/layer/104400-lcdb-v50-land-cover-database-version-50-mainland-new-zealand/

relied on solely for the Manuherikia catchments: further changes that have occurred since 2018 were also mapped.

The mapping that was completed for Canterbury in 2016 was partly verified using Farm Environmental Plans and feedback from irrigation schemes (Aqualinc, 2016). No further verification was completed in Canterbury for the current update.

Primary-sector verification for the Takaka catchment in the Tasman District was incorporated into the 2017 project (Dark et al, 2017). No further verification was completed in this catchment for the current update.

2.4 Update process

Within the time available for this project it has not been possible to re-analyse every irrigated area polygon that was mapped in the 2017 project.

The following process was used to identify and prioritise areas that required updating:

- Identify areas outside of 2017 irrigated land dataset that may be irrigated, based on NDVI and aerial / satellite photos.
- Identify areas within 2017 irrigated land dataset that may not be irrigated, based on NDVI and aerial / satellite photos (i.e. potential “false positives”)
- Identify irrigated areas associated with water take consents that were granted after Feb 2014 (i.e. after the production of the previous national consents layer).
- Identify system changes (e.g. border-dyke to spray).
- Adjust confidence ratings where new evidence exists.

2.5 Uncertainty

Qualitative confidence levels were assigned to each polygon that was mapped in the update process[6].

To put uncertainty bounds on the total area mapped, percentage error estimates were applied to each irrigation system type, and adjusted depending on the level of contrast between irrigated and non-irrigated areas.

2.5.1 Qualitative confidence levels

Each area that was mapped had a confidence level (high, medium, low) assigned to it.

In general, some system types tended to have higher confidence ratings. For example, centre pivot irrigators are typically highly visible as circles.

Qualitatively, the factors contributing to uncertainty in the mapped area include:

- Consent database errors
- Land under development
- Short-rotation crops that may not show up in aerial / satellite photos or NDVI imagery. This, combined with uncertainty about a property’s irrigation system capacity (l/s/ha) can result in a whole property being mapped as irrigated, when in fact only part of the property can be irrigated at any one time.

[6] Areas of Canterbury that were mapped in 2016 do not have confidence levels assigned to them.

- Difficulty in assigning individually-held surface water consents to properties when the irrigation system is not clearly visible.
- Recent conversions of previously irrigated urban-fringe land to housing.

2.5.2 Quantitative uncertainty estimates.

Generally there was a high degree of correlation between the irrigation system type and the degree of confidence in the mapping, for example centre-pivots can typically be mapped with a high degree of confidence. If the irrigation system type cannot be determined (i.e. it has been classified as “unknown”) the level of confidence in the mapped area is also likely to be low. Therefore the system type has been used to estimate the quantitative uncertainty of the mapping. The uncertainty percentages for each system type are based on our judgement of the degree of accuracy with which each system type can generally be mapped.

The percentage uncertainty assigned to each system type was scaled up for the moderate and low NDVI contrast regions (see Table 3) to reflect the increased difficulty in mapping irrigated areas when there is less contrast with surrounding unirrigated areas. The amount that the uncertainty estimates were scaled up in the moderate and low NDVI contrast regions depended on the irrigation system type. For example, centre pivots are relatively easy to identify in all regions, and therefore the estimated uncertainty was not increased greatly. For irrigation systems that required a greater level of contrast between irrigated and unirrigated land for accurate identification, such as k-lines and guns, the increase in the uncertainty levels for moderate and low contrast regions was greater.

The percentage uncertainty values shown in Table 3 are the same as were used in the 2017 mapping project.

Table 3: Estimated uncertainty levels based on system type and NDVI contrast

Irrigation system type	Estimated uncertainty		
	High NDVI-contrast	**Moderate NDVI-contrast**	**Low NDVI-contrast**
Pivot	2%	2%	3%
Lateral	2%	2%	3%
Drip/micro	5%	7%	9%
Roto-Rainer	5%	7%	12%
Linear boom	5%	7%	10%
K-line/Long lateral	6%	10%	15%
Solid set	5%	7%	10%
Gun	7%	10%	15%
Border dyke	5%	10%	15%
Side-roll	8%	12%	15%
Wild flooding	8%	12%	15%
Unknown	10%	15%	20%

2.6 Limitations of the dataset

The accuracy of the mapping varies between regions, depending on climate. In some areas, identification of irrigated land and irrigation system type is difficult due to the lack of visual contrast between irrigated and non-irrigated land.

Land used for short-rotation cropping may not be identifiable as irrigated if no crop was actively growing when the aerial photo or imagery was taken.

As discussed in Section 2.3, only field verification and primary sector validation of the datasets has been completed. No verification has been completed specifically for this project.

Any errors in the Councils' consent databases that were relied on by NIWA when they compiled the national water takes dataset may also result in errors in the mapping.

This dataset provides a national overview, and is not necessarily appropriate for use at farm or irrigation-scheme scale without validation. Before reliance is made on the spatial dataset in relation to specific catchments, irrigation schemes or farms, it is recommended that updated information should be sought from irrigation schemes and/or individual land-owners.

3 ATTRIBUTES OF THE SPATIAL DATASET

Details on the attributes supplied with data are given in Table 4.

Table 4: GIS data fields

Field	Description
type	Irrigation system type (see Table 5)
notes	Comments on issues that may affect accuracy; notes about the system type; unusual consented rates, etc.
area_ha	Mapped area in hectares
confidence	Qualitative confidence in the mapped area
year_irr	Year that mapping best represents (typically the year of the most recent aerial / satellite imagery dataset)
yearmapped	Year that mapping was completed
status	Current = most recent estimate Superseded = previous estimate (system changed or input data has allowed more accurate mapping)

In areas where the earlier mapping has been replaced in the current update, the entry in the "status" field has been changed to "Superseded", and the features have been retained in the spatial dataset.

Note that the total areas reported are based on current areas only. For any further analysis of the current areas, the superseded areas should be filtered out to avoid double-counting.

Table 5 provides further details on the irrigation types. Irrigation systems can be mapped as "unknown" system type but high confidence if the property is clearly irrigated (i.e. high NDVI contrast, evidence of a water source), but no irrigation equipment can be seen in aerial / satellite photos.

Table 5: Irrigation system types

System category	Name in spatial dataset	Other common names
Spray systems	Pivot	Centre-pivot
	Lateral	Linear move, Linear
	Roto-Rainer	Rotary Boom
	Linear boom	TurboRain
	K-line/Long lateral	Hand move, sprinklers, laterals
	Solid set	Fixed grid
	Gun	Big gun, Hard-hose gun
	Side-roll	Hand-shift roller
Drip / micro systems	Drip/micro	
Flood systems	Border dyke	
	Wild flooding	Contour irrigation
Unknown	Unknown	

Metadata and a data dictionary have been provided separately, as electronic files.

4 NATIONAL SUMMARY OF RESULTS

4.1 Total area

The total irrigated area that has been mapped in the updated dataset is 903,465 ha.

This is 14% higher than the area that was mapped in 2017. Although there has undoubtedly been an increase in the total irrigated area in recent years, this does not mean that the actual irrigated area has increased by 14%. Reasons for this include:

- Time-lags in the input datasets: the 2017 mapping primarily used aerial photos from 2015 or earlier, Landsat data from 2015, and consents data from 2013.
- The availability and update frequency of high-resolution aerial photography and multispectral satellite images has improved since 2017.
- The dry conditions experienced by much of New Zealand in early 2020 have allowed us to map some areas that were not possible to identify previously.

The 2017 Agricultural Production Statistics[7] give a total irrigated land area of 746,739 ha, which is a 21% difference from the area that we have mapped. A direct comparison cannot be made between the APS data and the spatial dataset due to the difference in methodology.

4.2 Summary by region

The total mapped area for each region is shown in Table 6, along with the percentage of the total area, and the percentage change in that region between the 2017 and 2020 spatial datasets. Although there are some large percentage changes, these are mostly in regions with a relatively small proportion of the total irrigated area. As discussed in Section 5, the total areas in some regions with a large percentage increase are now more consistent with the APS data.

[7] https://www.stats.govt.nz/information-releases/agricultural-production-statistics-june-2017-final-nz-stat-tables

Table 6: Summary of 2020 mapped irrigated area by region, with % change from 2017 dataset

Region	2020 Mapped irrigated area (ha)	% of total mapped area	% change from 2017 dataset
Auckland	9,938	1.1%	25%
Bay of Plenty	13,072	1.4%	67%
Canterbury	546,205	60.5%	8%
Gisborne	9,667	1.1%	49%
Greater Wellington	21,487	2.4%	22%
Hawkes Bay	43,473	4.8%	51%
Manawatu-Wanganui	27,480	3.0%	16%
Marlborough	35,351	3.9%	13%
Northland	12,337	1.4%	47%
Otago	111,082	12.3%	19%
Southland	22,254	2.5%	18%
Taranaki	4,567	0.5%	28%
Tasman	15,808	1.7%	33%
Waikato	26,307	2.9%	11%
West Coast	4,437	0.5%	23%
Total (ha)	**903,465**	**100%**	**14%**

The total mapped area, with the estimated uncertainty range, for each region is shown in Figure 3, along with the 2017 mapped totals and the 2017 APS data.

The percentage of the total area made up by each region is shown in Figure 4.

The total mapped area is summarised by region and system type in Table 7, along with uncertainty estimates and percentages by region and system type.

The percentage of the total area represented by each system type is shown in Figure 5.

The largest proportion of the total irrigated area is made up by centre pivots (39%), which is an increase of four percentage points from the 2017 dataset. 15% of the total area was mapped as “unknown” system type; this is a slight improvement on the 2017 dataset.

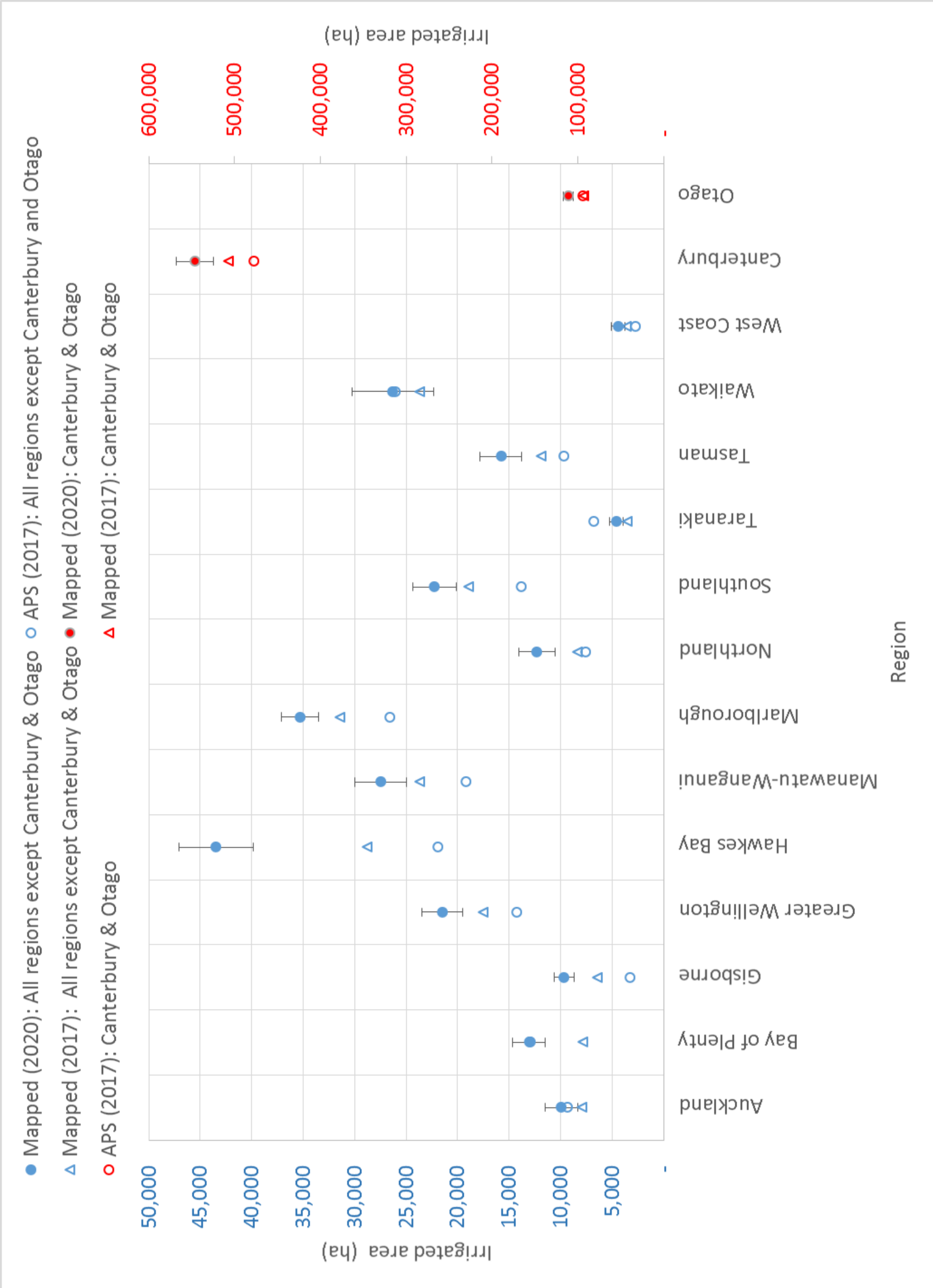

Figure 3: 2020 mapped areas by region, with uncertainty estimates, compared to 2017 mapped areas and 2017 APS data.

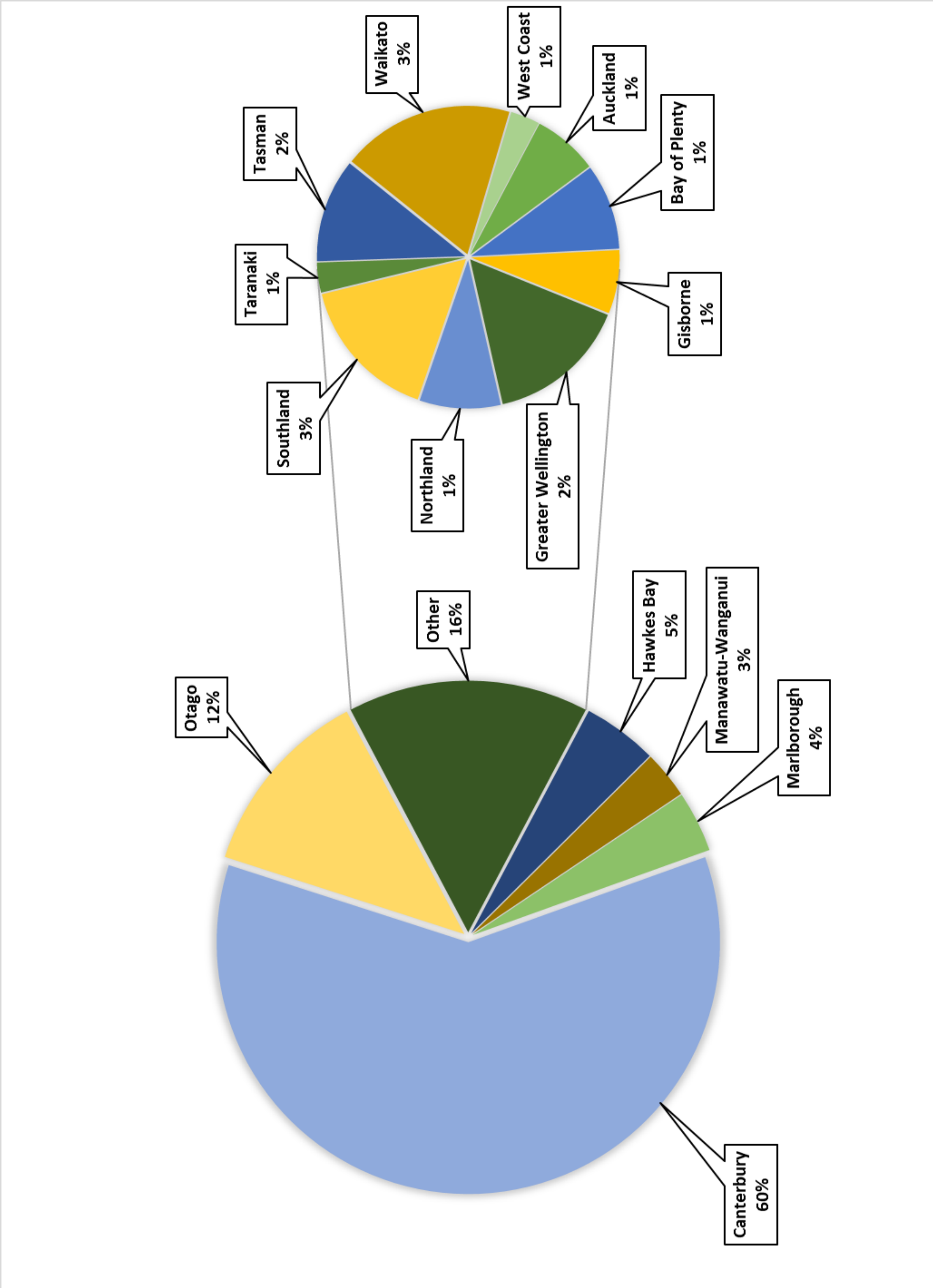

Figure 4: Percentage of total 2020 mapped area by region

Table 7: Summary of mapped irrigated area by system type and region.

Region	Border dyke	Drip/micro	Gun	K-line/ Long lateral	Lateral	Linear boom	Pivot	Roto-rainer	Side Roll	Solid-set	Wild flooding	Unknown	Total by region (ha)	Uncertainty (± ha)	% of total by region
Auckland		2,616	1,104	706	63		69					5,380	9,938	1,587	1.1%
Bay of Plenty		5,338	5	3,093			1,574					3,061	13,072	1,605	1.4%
Canterbury	18,657	2,738	29,036	43,346	32,778	9,511	279,570	73,715	247	3,811	889	51,906	546,205	21,583	60.5%
Gisborne	5	4,965	243	787			98			11		3,558	9,667	987	1.1%
Greater Wellington	80	2,815	734	5,969	97		4,818	36		35		6,903	21,487	2,014	2.4%
Hawkes Bay		16,331	13,198	617	409	20	6,673	120				6,105	43,473	3,592	4.8%
Manawatu-Wanganui		633	579	2,861	144	139	10,110	919		80		12,014	27,480	2,475	3.0%
Marlborough		28,609	721	1,512		469	1,990	617		20		1,415	35,351	1,808	3.9%
Northland		4,903	347	2,576			124					4,386	12,337	1,761	1.4%
Otago	12,827	3,849	3,628	27,484	193	163	35,783	3,911		681	8,966	13,596	111,082	5,771	12.3%
Southland		6	66	2,414	251		6,111	2,553		464		10,391	22,254	2,145	2.5%
Taranaki		18		284			1,423					2,841	4,567	655	0.5%
Tasman		6,286	123	4,985			996			299		3,118	15,808	2,015	1.7%
Waikato		1,564	2,826	3,927	221		4,401			233		13,136	26,307	3,943	2.9%
West Coast				2,217			761					1,459	4,437	647	0.5%
Total by system type (ha)	**31,569**	**80,671**	**52,609**	**102,780**	**34,156**	**10,302**	**354,501**	**81,871**	**247**	**5,633**	**9,855**	**139,271**	**903,465**	**52,590**	**100.0%**
% of total by system type	**3.5%**	**8.9%**	**5.8%**	**11.4%**	**3.8%**	**1.1%**	**39.2%**	**9.1%**	**0.0%**	**0.6%**	**1.1%**	**15.4%**			

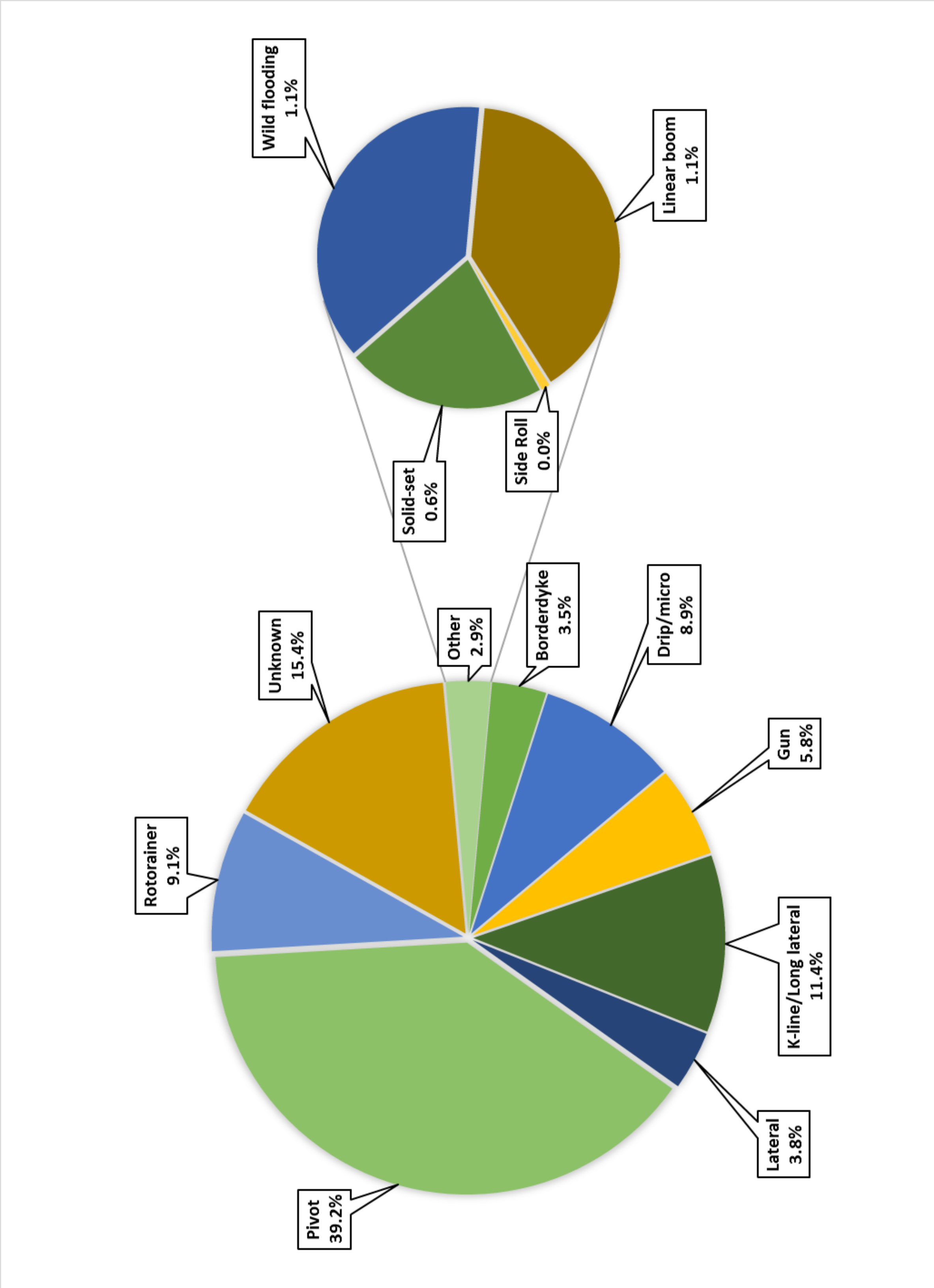

Figure 5: Percentage of 2020 mapped area by system type

5 REGIONAL RESULTS

The following sections summarise the total mapped area by region, and provide further details on the datasets used, and any issues encountered with mapping each region. The regions are grouped according to the levels of NDVI contrast (low, moderate, high).

5.1 High NDVI-contrast regions

Three regions – Canterbury, Marlborough and Otago – have been categorised as high NDVI contrast regions, where there was typically very clear contrast between irrigated and unirrigated areas. Together these three regions make up 77% of the total mapped irrigated area,

5.1.1 Canterbury

A total of 546,205 ha has been mapped in Canterbury. This is an increase of 8% from the 2017 dataset. For comparison, the 2017 APS data gives a total of 478,143 ha. We are aware of a number of new irrigation developments that have occurred since the 2017 datasets were produced, including Central Plains Water Stage II and Sheffield, and the conversion of the Eyrewell Forest to pasture.

The mapped area for Canterbury is summarised by system type in Table 8.

Table 8: Canterbury: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Borderdyke	18,657	3%	5%	933
Drip/micro	2,738	1%	5%	137
Gun	29,036	5%	7%	2,033
K-line/Long lateral	43,346	8%	6%	2,601
Lateral	32,778	6%	2%	656
Linear boom	9,511	2%	5%	476
Pivot	279,570	51%	2%	5,591
Rotorainer	73,715	13%	5%	3,686
Side Roll	247	<1%	8%	20
Solid-set	3,811	1%	5%	191
Wild flooding	889	<1%	8%	71
Unknown	51,906	10%	10%	5,191
Totals:	**546,205**	**100%**		**21,583**

For rural Canterbury, 0.3 m pixel aerial photos from 2017 – 2018 were available. Some irrigated areas were also captured by Christchurch urban aerial phots from 2018, which have a 0.075 m pixel size.

Centre-pivots account for the majority of irrigated area in Canterbury: 51%.

The percentage of border-dyke has reduced from 5% to 3%. In most cases, areas that have been converted from border-dyke have been replaced by pivots.

5.1.2 Marlborough

A total of 35,351 ha was mapped in Marlborough. This is a 13% increase from the 2017 mapped area. For comparison, the 2017 APS data gives a total of 26,613 ha.

The mapped area for Marlborough is summarised by system type in Table 9. Drip / micro irrigation (primarily vineyards) makes up 81% of the total irrigated area in Marlborough.

Table 9: Marlborough: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	28,609	81%	5%	1,430
Gun	721	2%	7%	50
K-line/Long lateral	1,512	4%	6%	91
Linear boom	469	1%	5%	23
Pivot	1,990	6%	2%	40
Rotorainer	617	2%	5%	31
Solid-set	20	<1%	5%	1
Unknown	1,415	4%	10%	141
Totals:	**35,351**	**100%**		**1,808**

For rural Marlborough, 0.3 m pixel aerial photographs from 2017 – 2018 were available. Some irrigated areas were also covered by 0.1 m urban area aerial photos from 2017.

As discussed in Section 2.3, a vineyards layer from Marlborough District Council was utilised in the mapping update.

5.1.3 Otago

A total of 111,082 ha has been mapped in Otago, which is 19% greater than the area mapped in 2017. For comparison, the 2017 APS data has a total area of 94,152 ha.

The mapped area for Otago is summarised by system type in Table 10. The most prevalent system type is pivots (32%); this is an increase of five percentage points from the 2017 mapping. The area of borderdyke has reduced from 15% to 12%.

Table 10: Otago: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Borderdyke	12,827	12%	5%	641
Drip/micro	3,849	3%	5%	192
Gun	3,628	3%	7%	254
K-line/Long lateral	27,484	25%	6%	1,649
Lateral	193	<1%	2%	4
Linear boom	163	<1%	5%	8
Pivot	35,783	32%	2%	716
Rotorainer	3,911	4%	5%	196
Solid-set	681	1%	5%	34
Wild flooding	8,966	8%	8%	717
Unknown	13,596	12%	10%	1,360
Totals:	**111,082**	**100%**		**5,771**

Aerial photos with a 0.3 m pixel size were available for rural Otago from 2017 – 2019. Some irrigated areas were also captured in the 0.1 m urban aerial photos from 2018.

As discussed in Section 2.3, field-verified data from 2018 for the Manuherikia catchment was incorporated into the updated dataset.

5.2 Moderate NDVI-contrast regions

Gisborne, Hawke's Bay, Manawatu-Wanganui, Southland and Greater Wellington were categorised as having moderate NDVI contrast. In these regions there was generally good contrast between irrigated and unirrigated area, however this varied between regions, and within individual regions. Between them, these regions make up 14% of the total mapped area.

5.2.1 Gisborne

A total of 9,667 ha has been mapped for the Gisborne District, which is 49% greater than the area mapped in 2017. For comparison the 2017 APS data has a total of 3,240 ha[8].

The mapped area for Gisborne is summarised in Table 11. The majority (51%) of the area has been mapped as drip / micro, which is consistent with the land-uses in the district.

[8] The 2012 APS data had a total of 4,461 ha for Gisborne. Based on anecdotal information about development and water allocation in the Gisborne District, we consider it highly unlikely that the irrigated area in the district actually decreased in the 2012 – 2017 period.

Table 11: Gisborne: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Borderdyke	5	<1%	10%	0
Drip/micro	4,965	51%	7%	348
Gun	243	3%	10%	24
K-line/Long lateral	787	8%	10%	79
Pivot	98	1%	2%	2
Solid-set	11	<1%	7%	1
Unknown	3,558	37%	15%	534
Totals:	**9,667**	**100%**		**987**

In the report accompanying the 2017 mapping (Dark et al, 2107), it was noted that there were a number of areas in Gisborne that had been mapped as irrigated, but had no consents associated with them. The updated consents data shows a substantial number of new consents. It is still difficult in some cases, however, to determine which areas area are actually irrigated where there are nearby land-parcels with similar land-uses but not all have a resource consent associated with them. It is possible that some consents are only for “drought insurance” (i.e. the land-use can occur without irrigation, but at a higher level of risk), or that smaller areas are being irrigated under permitted activity rules.

Aerial photos with a 0.3 m pixel size for the Gisborne rural area and a 0.1 m pixel size for the urban area were available for the from 2017 – 2018.

5.2.2 Hawke’s Bay

A total of 43,473 ha was mapped for Hawke’s Bay, which is 51% higher than the area that was mapped in 2017. For comparison, the 2017 APS data has a total of 21,945 ha.

The mapped area for Hawke’s Bay is summarised by system type in Table 12. The most prevalent irrigation system type is drip / micro (38%).

Table 12: Hawke’s Bay: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	16,331	38%	7%	1,143
Gun	13,198	30%	10%	1,320
K-line/Long lateral	617	1%	10%	62
Lateral	409	1%	2%	8
Linear boom	20	<1%	7%	1
Pivot	6,673	15%	2%	133
Rotorainer	120	<1%	7%	8
Unknown	6,105	14%	15%	916
Totals:	**43,473**	**100%**		**3,592**

A number of different aerial photo datasets were available for Hawkes Bay:

- 0.3 m resolution rural area, 2014 – 2015,
- 0.1 m resolution Hastings District urban areas, 2017 – 2018,

- 0.1 m resolution Central Hawkes Bay, 2017 – 2018,
- 0.1 m resolution Napier urban areas, 2017 – 2018.

We are aware that in Hawkes Bay a lot of land is leased, and irrigation equipment (hard-hose guns, for example) is transferred between blocks of land. This is a possible explanation for some of the difference between the two 2017 and 2020 spatial datasets, and between the mapping and the APS data.

5.2.3 Manawatu-Wanganui

A total of 27,480 ha was mapped for Manawatu-Wanganui, which is 16% higher than the area mapped in 2017. For comparison, the 2017 APS data has a total of 19,177 ha.

The mapped area for Manawatu-Wanganui is summarised by system type in Table 13. Pivots are the most prevalent system type (37%), and approximately 40% of the difference between the 2017 and 2020 datasets is accounted for by pivots.

Table 13: Manawatu-Wanganui: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	633	2%	7%	44
Gun	579	2%	10%	58
K-line/Long lateral	2,861	10%	10%	286
Lateral	144	1%	2%	3
Linear boom	139	1%	7%	10
Pivot	10,110	37%	2%	202
Rotorainer	919	3%	7%	64
Solid-set	80	<1%	7%	6
Unknown	12,014	44%	15%	1,802
Totals:	**27,480**	**100%**		**2,475**

The following aerial photos datasets were available for Manawatu-Wanganui:

- 0.3 m resolution rural areas, 2016 – 2017,
- 0.125 m resolution Manawatu urban areas, 2019,
- 0.075 m resolution Whanganui urban area, 2017.

5.2.4 Southland

A total of 22,254 ha was mapped for Southland, which is 18% greater than the area mapped in 2017. For comparison, the 2017 APS data gives a total area of 13,800 ha.

The mapped area for Southland is summarised by system type in Table 14. A high proportion (47%) of the irrigation system types were unable to be identified, although this has improved relative to the 2017 mapping. Based on our knowledge of land-use in Southland, it is likely that many of the areas where the system was unable to be identified are irrigated by spray systems such as K-line. Of the irrigation systems that are able to be identified, the majority are pivots (27% of total), and the increase in pivots relative to 2017 accounts for almost all of the difference in total area between the two datasets.

Table 14: Southland: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	6	<1%	7%	0
Gun	66	<1%	10%	7
K-line/Long lateral	2,414	11%	10%	241
Lateral	251	1%	2%	5
Pivot	6,111	27%	2%	122
Rotorainer	2,553	11%	7%	179
Solid-set	464	2%	7%	32
Unknown	10,391	47%	15%	1,559
Totals:	**22,254**	**100%**		**2,145**

As discussed in Section 2.2, although multispectral satellite data from 2020 was available for Southland, we used data from 2018 as this more representative of dry conditions.

The following aerial photo datasets were available for Southland:

- 0.4 m resolution rural areas, 2015 – 2017.
- 0.1 m and 0.05 m resolution Invercargill urban areas, 2016.

5.2.5 Greater Wellington

A total of 21,487 ha was mapped for the Greater Wellington Region, which is 22% greater than the area mapped in 2017. For comparison, the 2017 APS data gives a total of 14,284 ha.

The mapped area for Greater Wellington is summarised by system type in Table 15. Of the irrigation systems that can be identified, the majority have been classified as K-line / long lateral (28% of total).

Table 15: Greater Wellington: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Borderdyke	80	<1%	10%	8
Drip/micro	2,815	13%	7%	197
Gun	734	3%	10%	73
K-line/Long lateral	5,969	28%	10%	597
Lateral	97	<1%	2%	2
Pivot	4,818	22%	2%	96
Rotorainer	36	<1%	7%	3
Solid-set	35	<1%	7%	2
Unknown	6,903	32%	15%	1,036
Totals:	**21,487**	**100%**		**2,014**

Aerial photos from 2016 – 2017 with a 0.3 m pixel size were available for rural areas. Aerial photos with a 0.1 m pixel size were available for the Wellington, Hutt Valley and Kapiti Coast urban areas from 2017.

5.3 Low NDVI contrast regions

Auckland, Bay of Plenty, Northland, Taranaki, Tasman, West Coast and Waikato were categorised as having low NDVI contrast.

As discussed in Section 2.2.3, due to the dry conditions in early 2020, there was significantly greater contrast in many areas than in the datasets used for the 2017 study.

Some common challenges faced in the low-NDVI regions included:

- On some properties the actual extent of the irrigated area is unclear and is difficult to infer from the consented rate of take.
- Maximum consented rates (particularly for surface water takes) do not always correspond well to the irrigated areas. In some cases the irrigation system capacity (l/s/ha) may be much lower than would be expected in drier regions; in others the consented rate may account for a peak diversion rate or storage refill, rather than the average rate that water is applied to land.
- Smaller horticultural properties may be irrigated under permitted activity rules.

5.3.1 Auckland

The total area mapped in the Auckland Region was 9,938 ha, which is 25% greater than the area mapped in 2017. For comparison, the 2017 APS data has a total of 9,344 ha.

The mapped area for the Auckland Region is summarised by system type in Table 16. The majority of system types (54%) were not able to be identified. Of the remaining area, the prevalent system type was drip /micro.

Table 16: Auckland: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	2,616	26%	9%	235
Gun	1,104	11%	15%	166
K-line/Long lateral	706	7%	15%	106
Lateral	63	1%	3%	2
Pivot	69	1%	3%	2
Unknown	5,380	54%	20%	1,076
Totals:	**9,938**	**100%**		**1,587**

Aerial photos from 2017 with a pixel size of 0.075 m were available for the Auckland urban area. Some of South Auckland is covered by Waikato rural aerial photos from 2016 – 2019, which have a pixel size of 0.3 m.

5.3.2 Bay of Plenty

The total mapped area for Bay of Plenty was 13,072 ha, which is a 67% greater than the area mapped in 2017. For comparison, the 2017 APS data gives a total area of 12,956 ha[9].

[9] The area mapped in 2017 was approximately two-thirds of the 2012 APS total of 11,610 ha.

The mapped area for Bay of Plenty is summarised by system type in Table 17. The most prevalent system type is drip / micro (41%). The area mapped as spray (K-line and pivots) has increase by 14 percentage points, and the proportion of the total area with unknown system type has reduced by 10 percentage points.

Table 17: Bay of Plenty: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	5,338	41%	9%	480
Gun	5	<1%	15%	1
K-line/Long lateral	3,093	24%	15%	464
Pivot	1,574	12%	3%	47
Unknown	3,061	23%	20%	612
Totals:	**13,072**	**100%**		**1,605**

Aerial photo datasets available for Bay of Plenty included:

- 0.3 m resolution Eastern Bay of Plenty rural areas, 2019,
- 0.1m resolution urban areas, 2018-2019,
- 0.3m resolution rural areas, 2016-2017.

5.3.3 Northland

The total mapped area for Northland was 12,337 ha, which was 47% greater than the area mapped in 2017. For comparison, the 2017 APS data gives a total area of 7,582 ha.

The mapped area for Northland is summarised by system type if Table 18. The most prevalent system type is drip / micro (40%). The proportion of area with an unidentifiable system type has increased by 6 percentage points relative to the 2017 mapping. Anecdotally, there have been a substantial number of new orchard developments in Northland, and some development of dairy farms, in recent years.

Table 18: Northland: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	4,903	40%	9%	441
Gun	347	3%	15%	52
K-line/Long lateral	2,576	21%	15%	386
Pivot	124	1%	3%	4
Unknown	4,386	36%	20%	877
Totals:	**12,337**	**100%**		**1,761**

The most recent aerial photo dataset available for Northland was 0.4m pixel size from 2014 – 2016.

5.3.4 Taranaki

The total mapped area for Taranaki was 4,567 ha, which is 28% greater than the area that was mapped in 2017. For comparison, the 2017 APS data give a total of 6,803 ha[10].

The mapped area for Taranaki is summarised by system type in Table 19. The majority of the mapped area (62%) did not have an identifiable system type. The total area of pivots has increased, but the majority of the new area that has been mapped in this update is of unknown system type.

Table 19: Taranaki: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	18	<1%	9%	2
K-line/Long lateral	284	6%	15%	43
Pivot	1,423	31%	3%	43
Unknown	2,841	62%	20%	568
Totals:	**4,567**	**100%**		**655**

Aerial photos from 2016 – 2018 with a 0.3 m pixel size were available for Taranaki.

5.3.5 Tasman

A total of 15,808 ha was mapped in the Tasman District, which is 33% greater than the area that was mapped in 2017. For comparison, the 2017 APS data gives a total area of 9,679 ha.

The mapped area for Tasman is summarised by system type in Table 20. The prevalent system type is drip / micro (40%).

Table 20: Tasman: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	6,286	40%	9%	566
Gun	123	1%	15%	18
K-line/Long lateral	4,985	32%	15%	748
Pivot	996	6%	3%	30
Solid-set	299	2%	10%	30
Unknown	3,118	20%	20%	624
Totals:	**15,808**	**100%**		**2,015**

As discussed in Section 2.3, the Takaka catchment was mapped prior to the 2017 project, for the Wheel of Water research programme (MBIE contract CONT-24535-LFR-AQUALINC). This mapping, which had been verified with local land-owners, was integrated into the 2017 dataset, and updated as required. Further updates to areas in the Takaka catchment were made in the current project.

For the Tasman District aerial photos from 2018 - 2019 with a 0.3 m resolution were available for rural areas, and photos from 2017 with a 0.1 m resolution were available for urban areas.

[10] The 2012 APS area (6,505 ha) was also greater than the 2017 mapped area.

5.3.6 Waikato

The total mapped area for Waikato was 26,307 ha, which is 11% greater than the area mapped in 2017. For comparison, the 2017 APS data gives a total area of 26,077 ha.

The mapped area for the Waikato Region is summarised by system type in Table 21. Half of the mapped area has an unidentifiable system type. Of the systems that can be identified, the majority are spray: gun, K-line / long lateral, and pivots.

Table 21: Waikato: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
Drip/micro	1,564	6%	9%	141
Gun	2,826	11%	15%	424
K-line/Long lateral	3,927	15%	15%	589
Lateral	221	1%	3%	7
Pivot	4,401	17%	3%	132
Solid-set	233	1%	10%	23
Unknown	13,136	50%	20%	2,627
Totals:	**26,307**	**100%**		**3,943**

Aerial images for rural Waikato, with a 0.3 m pixel size, were available from 2016 – 2019.

5.3.7 West Coast

The total mapped area for the West Coast region was 4,437 ha, which is 23% greater than the area mapped in 2017. For comparison, the 2017 APS data gives a total area of 2,780 ha.

The mapped area for the West Coast is summarised by system type in Table 22. The most prevalent system type is K-line / long lateral.

Table 22: West Coast: mapped irrigated area by system type, with estimated uncertainty.

Irrigation system type	2020 Mapped area (ha)	% of 2020 mapped area in region	Estimated uncertainty	
			% uncertainty	Area (± ha)
K-line/Long lateral	2,217	50%	15%	333
Pivot	761	17%	3%	23
Unknown	1,459	33%	20%	292
Totals:	**4,437**	**100%**		**647**

Aerial photos for the West Coast, with a 0.3 m pixel size, were available from 2016 – 2017, and 2015 – 2016.

6 CONCLUSIONS

The updated national irrigated land spatial dataset covers a total of 903,465 ha. This is an increase of 109,022 ha, or 14%, from the area that was mapped in 2017 using the same methodology. Although there has been an increase in irrigated land area between 2017 and 2020, the actual increase in irrigated area over this period is unlikely to be as great as the increase in mapped area. There are a several reasons for this, including:

- Time-lags in the input datasets that were used in the 2017 project (i.e. many of the areas mapped in 2017 may have been more representative of 2014 – 2015).
- The increasing availability of higher resolution aerial photos and multi-spectral satellite imagery, which has enabled us to identify and map areas with greater accuracy.
- The very dry conditions in many parts of New Zealand in early 2020 have made it easier to map areas where irrigation does not necessarily occur every summer, or where there is normally very low contrast (in visual or multispectral images) between irrigated and non-irrigated land.

Data from the 2017 Agricultural Production Statistics (APS) can be used as a partial benchmark for the total mapped area and the regional totals, although a direct comparison is not possible as the two datasets have been compiled using different methodologies, and there is a time-lag between them. The total mapped area for New Zealand is 21% greater than the area reported in the 2017 APS data. The area that was mapped in 2017 was 10% higher than the total reported in the 2012 APS data.

The majority of New Zealand's irrigated area (77%) is located in the drier east coast regions of the South Island: Marlborough, Canterbury and Otago. Canterbury alone accounts for 61% of the national total.

In four out the seven regions classified as having low NDVI contrast (Auckland, Bay of Plenty, Taranaki and Waikato), the updated mapped areas are a reasonably close match to the 2017 APS data. This indicates that in the updated dataset we have been able to map irrigated areas in these regions more accurately than before.

Several regions (most notably Hawkes Bay, Gisborne, Northland and Tasman) have had large percentage increases relative to the 2017 mapped areas, and the totals are not a particularly close match to the areas reported in the APS data. Although we are aware of new irrigation development in all of these areas, the total change is likely to be a combination of actual increases in area, under-reporting in the 2017 mapping (due to area not be identifiable), and uncertainty in identification of areas added to the updated dataset.

The most prevalent irrigation system type is centre-pivot, making up 39% of the total irrigated area. This is a four percentage point increase from the 2017 dataset, and accounts for more than a third of the total change in area between the 2017 and 2020 spatial datasets.

7 RECOMMENDATIONS

The national dataset provides a useful start-point for creating verified / validated (using field verification, local knowledge, or other validation from the primary sector) irrigated area datasets at regional / catchment scale. Validated data should then be incorporated back into the national dataset. This approach was used with the Manuherikia catchment in Otago. Validation would be particularly useful in areas where a high proportion of irrigated area have been mapped with low confidence and / or unknown system type, or where there are a lot of smaller horticultural properties and properties with the same land-use may or may not be irrigated.

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Appendix A: Normalised Difference Vegetation Index.

The normalised difference vegetation index (NDVI) is calculated as follows:

$$NDVI = \frac{(NIR - R)}{(NIR + R)}$$

Where R is reflection in the red range of the visible (Band 4; 665 nm), and NIR is reflection in the near-infrared spectrum (Band 8; 842 nm)[11].

[11] https://sentinel.esa.int/web/sentinel/user-guides/sentinel-2-msi/resolutions/spatial