PFR SPTS No. 19274

Evaluation of selected horticultural crops for Kaipara District Council: Progress Report 3

Ward R, Clothier B

March 2020















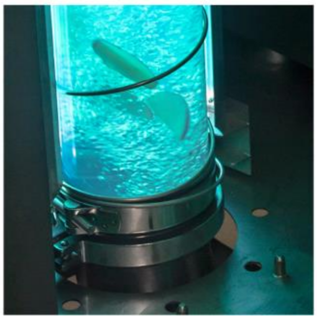


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Report approved by:

Brent Clothier
Principal Scientist, Land Use Impacts
March 2020

Paul Johnstone
Science Group Leader, Cropping Systems & Environment
March 2020

Contents

Executive summary

Evaluation of selected horticultural crops for Kaipara District Council: Progress Report 3

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Plant & Food Research: Palmerston North

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We have carried out an assessment of the suitability across the Kaipara District for the arable cropping of sorghum, soybeans and peanuts. These crops present an opportunity to be incorporated into cropping rotations with existing agricultural systems in the Kaipara District. We have reviewed earlier reports on the growing of these crops in New Zealand, and especially Northland. We also discuss the potential for these crops to be grown in rotation with each other, or with existing crops growing in the Kaipara District. For all crops, matching cultivar selection to location will be important to ensure the local weather and soil conditions are appropriate.

In a generic sense we consider that arable cropping could be carried out across some 130,000 ha of the Kaipara District. We examined this in more detail using six geographically representative Virtual Climate Station Network (VSCN) sites to assess the need for irrigation, as well as the likely dates for sowing and harvest dates for cultivars having varying seasonal length requirements.

We have predicted the likely impact of droughts on crop production. We computed the soil water deficit (SWD) at each VCSN station and compared that with the readily available water (RAW) in each area to give an estimate of how much irrigation might be needed over the growing season. The SWD was simply calculated as the difference between the rainfall and the potential evapotranspiration (PET), both of which are available data products for the VCSN. On average, there will need to be approximately 40–50 mm of total irrigation in the wettest areas on soils with higher RAWs, and around 250 mm of total irrigation in the driest areas on soils with lower RAWs. There is large variability between years in these requirements. On average, all but the wettest areas appear to need irrigation beginning from sometime in November or December.

It is likely that peanuts would be best suited to the sandy soils in the west of Kaipara District, especially on the Pouto Peninsula, whereas soybeans and sorghum would be better suited to the heavier textured soils surrounding the Kaipara Harbour and Ruawai, plus those in the east towards Mangawhai. Choice of soybean and sorghum cultivar will be critical to ensure that the crops can reach grain maturity. Sorghum could also be used as a greenfeed crop with multiple cuts or grazings, or it could be grown for conserved feed in the form of silage.

We have also quantified the earliest date at which the crops could be planted on the basis of soil temperature. We consider that planting could begin in early October, local rainfall conditions in any given year notwithstanding.

Then by considering the seasonal growth in the Growing Degree Days, base 10°C, (GDD_{10}), we have assessed the probable grain-harvest dates and the likelihood of these crops reaching grain maturity as a function of VCSN location and season-length cultivars.

- Sorghum: Short-season cultivars are predicted to reach harvest maturity in mid- to late-April, and in over 85% of years there will be sufficient GDD_{10} to enable this. Long-season cultivars could be harvested in late May, and depending on VCSN location this would only be achieved in 10–35% of years.
- Soybean: Short-season cultivars are predicted to reach harvest maturity in late March to early April, and in over 97% of years there will be sufficient GDD_{10} to enable this. Long-season cultivars could be harvested in early to mid-May, and depending on VCSN location this would only be achieved in 50–80% of years.
- Peanuts: Short-season cultivars are predicted to reach harvest maturity in mid-April, and in over 90% of years there will be sufficient GDD_{10} to enable this. Long-season cultivars could be harvested in early May, and depending on VCSN location this would only be achieved in 60–90% of years.

In our next report, we will provide an assessment of the likely impacts of climate change on our assessments for the six crops we have considered. We will use the various RCP (Representative Concentration Pathway) climate-change projections for the six VCSN stations that we have been provided by NIWA.

For further information please contact:

Brent Clothier
Plant & Food Research Palmerston North
Private Bag 11600
Palmerston North 4442
NEW ZEALAND

Tel: +64 6 953 7700
DDI: +64 6 953 7687
Fax: +64 6 351 7050
Email: Brent.Clothier@plantandfood.co.nz

1 Introduction and background

In the second Progress Report by The New Zealand Institute for Plant and Food Research Limited (PFR) for this Kaipara Kai project, we discussed the potential for, and likely areas where crops of olives, avocados, and hemp, hops and CBD cannabis could be grown. Now in this third Progress Report we consider the potential for, and likely areas where the crops of:

- sorghum
- soybeans, and
- peanuts

might be grown. These three crops were chosen following consultation and discussions with the Kaipara District Council and Tim Morris of Coriolis Research. There were many linked reasons behind the rationale for the choice of this second tranche of three crops. These include:

- Sorghum. During the late 1970s and 1980s there was interest in growing sorghum, and many trials were carried out throughout New Zealand, and in Northland in particular, to overcome the problems caused by drought on pasture growth. Thus we were able to access agronomic information on sorghum production to assess the suitability for growing it in Kaipara District.

- Soybeans. Coriolis Research noted that soybeans are New Zealand's second-most imported animal and food crop. And by analogy of Kaipara with North Carolina, Coriolis Research found that soybeans are used in North Carolina in rotation with sweet potato, *inter alia*. So it should be possible that they could fit in, as a rotation crop, with kumara production in Kaipara. Also, PFR is interested in further developments in relation to plant-protein crops. A recent PFR report (Sutton et al. 2017) considered that "… *the opportunity for New Zealand is in manufacturing high-value plant protein foods, sourcing ingredient streams from trusted sustainable and diversified production systems that meet our future climate change challenges, and delivering premium products into the 'flexitarian' diets of our international customers*".

- Peanuts are part of the current Sustainable Food and Fibre Futures (SFFF) project with PFR, which commenced just after the beginning of this Kaipara Kai project. Peanuts would be suited, we surmised, to the sandy soils of the Pouto Peninsula. Unfortunately, by the time the SFFF project was confirmed it became too late to plant a trial on Pouto in 2019. However, PFR has planted a small trial in both a glasshouse and in the field at our Hawke's Bay Research Station, which will give us preliminary data in advance of a field trial at Pouto next year. The results from this Kaipara Kai project will identify likely planting dates, and possible areas where to grow peanuts with the Kaipara District.

- Whereas peanuts are, we considered, better suited to sandy soils of the Pouto Peninsula, soybeans and sorghum are likely to be less so, as the land there is LUC 4e-8e meaning there is a limitation due to erosion, i.e. primarily wind erosion. Therefore the regular tillage for soybeans and sorghum might pose a risk. Furthermore, if sorghum or soybeans are to be grown in rotation with kumara, these would be better suited, we thought, to land where kumara is now being grown around Ruawai, and other parts of the Kaipara District.

Here we consider the land area that would be potentially suitable for these crops, based on Land Use Capability class (LUC) and slope. As well, we identify areas where the soil's available water holding capacity is low, and hence irrigation, or judicious selection of crop type and cultivar, might be needed.

Next we discuss the climate constraints for each of these three crops and discuss published work on the uses of the crops and their likely yield. Where possible we highlight results from trials in New Zealand.

Finally, we have used this climatic information, in conjunction with weather data from six Virtual Climate Station Network (VCSN) sites (Table 1, NIWA (2020)) in the Kaipara, to examine likely sowing dates and harvest dates for a range of maturity cultivars of sorghum, soybeans and peanuts.

Table 1. List of VCSN stations used in this report.

VCSN station number	Location	Latitude	Longitude
20478	Waipoua	35.675°S	173.525°E
21434	Te Kopuru	36.125°S	173.925°E
25588	Mangawhai	36.125°S	174.525°E
27564	Ruawai	36.075°S	174.025°E
28751	Dargaville	35.925°S	173.875°E
29120	Pouto	36.325°S	174.075°E

In our next report, we will use future climate projections for these VCSN stations to assess the impacts and trade-offs that will result from climate change.

2 Cropping potential

At a generic level, we consider that for these three crops the following criteria need to be fulfilled:

- For sorghum and soybeans, we consider the land should fall within Land Use Capability (LUC) classes 1–4. Lynn et al. (2009) considered that "… *LUC Classes 1 to 4 are suitable for arable cropping (including vegetable cropping)*". As we did in our first Progress Report, we also consider that especially for peanuts, the classes of LUC 6e to 7e would also be suitable if appropriate land management of these mainly sandy soils on the Pouto Peninsula were implemented to prevent wind erosion.
- The land should have slope less than 15° to enable trafficking with machinery.
- The potential of land to support summer crops will be greater for soils having a higher water holding capacity, and we present maps of the available water holding capacity of Kaipara soils.

2.1 Land suitability for arable cropping

In Figure 1 we present a map of the land areas we consider suitable for arable cropping. This covers LUC classes 1 to 4, plus the area of the Pouto Peninsula with LUC classes 6e and 7e. All the areas shown in Figure 1 also have slopes less than 15°. In total, within the Kaipara District there are some 130,000 ha we consider suitable for arable cropping. This comprises 119,000 ha of land with LUC 1 to 4, plus 11,000 ha of land in LUC 6e and 7e primarily on the Pouto Peninsula. One constraint would be drought, so arable cropping would be favoured on soils with higher water holding capacities, unless irrigation were an option.

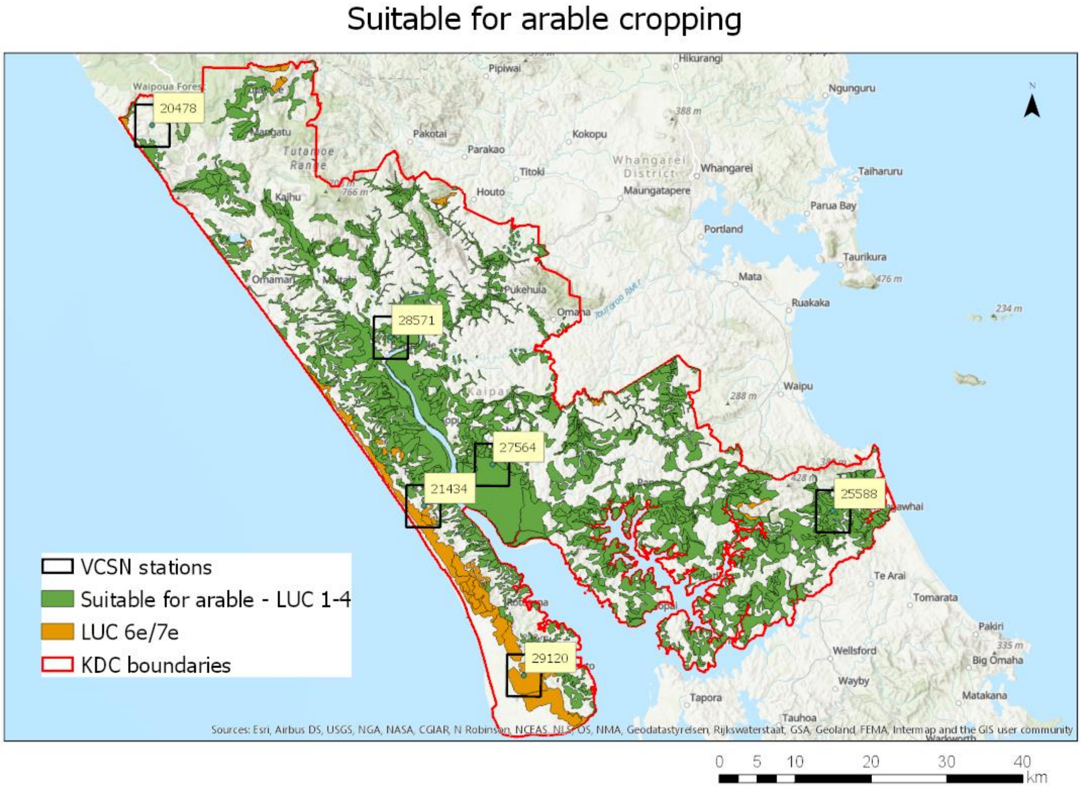

Figure 1. The areas suitable for arable cropping comprising lands of Land Use Capability (LUC) classes 1 to 4 (green), and LUC classes 6e and 7e (brown). Both these highlighted areas also have slopes less than 15°. Also shown are the 5 x 5 km grid squares associated with six representative Virtual Climate Station Network (VCSN) sites.

2.2 Soil water availability

From Manaaki Whenua – Landcare Research's Fundamental Soils Layers (FSL, Manaaki Whenua - Landcare Research (2020)) we can produce maps of total profile available water (TAW) and readily available water (RAW). Webb and Wilson (1995) define TAW as being the water held by the soil between the pressure potentials of -10 kPa (-0.1 bar) and -1500 kPa (-15 bar) in the top 0.4 m of the profile, plus the water held by the soil in the deeper layers between -10 kPa and -100 kPa (-1 bar). The depth of the soil is considered to be either the Potential Rooting Depth (PRD) as found in the FSL, or 0.9 m, whichever is shallower.

A map of the RAW for Kaipara District is presented as Figure 2. Webb and Wilson (1995) categorise RAW as being Very Low (< 25–150 mm), and Very High (> 150 mm). A useful rule-of-thumb is that peak evapotranspiration from a well-watered full-cover crop is of the order of 25 mm per week. So soils with a Low RAW (25–50 mm) would be able to sustain crop water-use for 1–2 weeks without rain, and those of Moderate RAW could supply the crop for about 2–3 weeks in the absence of rain, and so on. Thus care would be needed with cropping in the absence of irrigation, especially on the Pouto Peninsula.

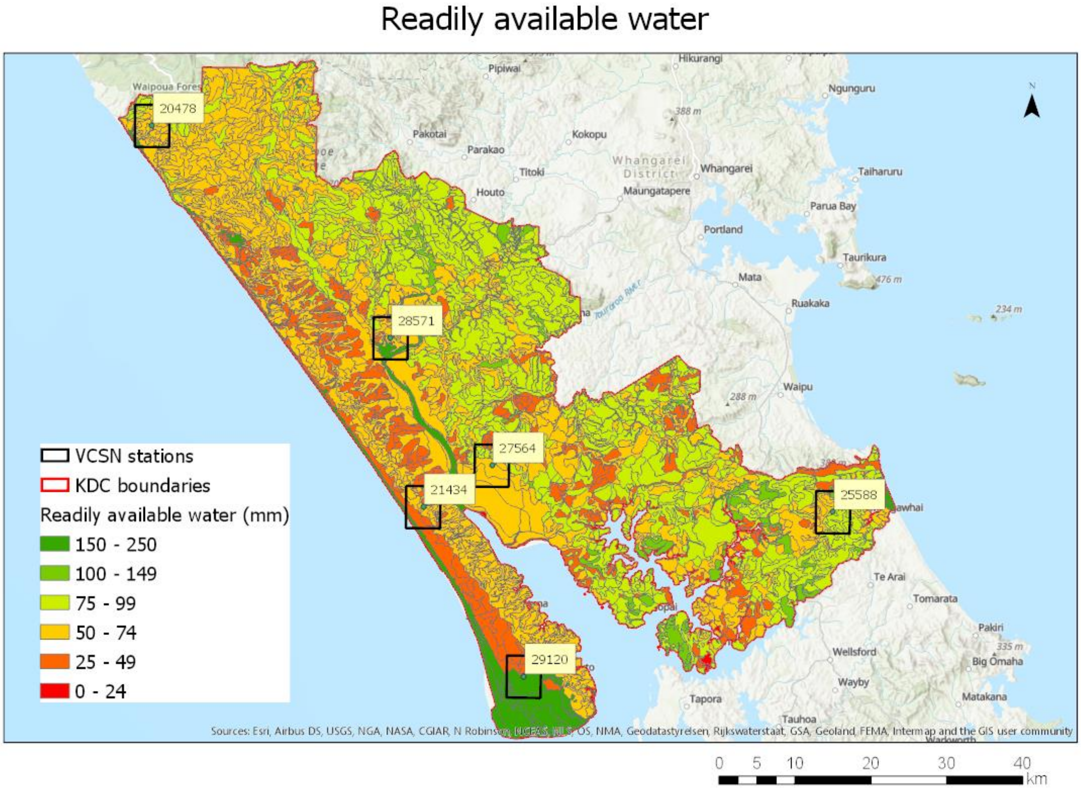

Figure 2. A map of the readily available water (RAW, mm) holding capacity of the soils of the Kaipara District (from Manaaki Whenua-Landcare Research's Fundamental Soils Layers).

We can examine the computed soil water deficit (SWD) at each VCSN station and compare that with the RAW in each area to give an estimate of how much irrigation might be needed over the growing season. The SWD is simply calculated here as the difference between the rainfall and the potential evapotranspiration (PET), both of which are available data products for the VCSN. Figure 3 shows the weekly SWD from 1 October to 28 February for each of the six VCSN stations and for all years of the VSCN data. For each station, an approximate RAW from Figure 2 is shown (red dashed line, 62.5mm for Figure 3a, b, d and f, 32.5mm for Figure 3c and e) and a line of best fit is shown (red solid line). While there is large variability in SWD by the end of growing season, all areas would require at least some irrigation in most years. On average, this will be approximately 40–50 mm of total irrigation in the wettest areas and around 250 mm of total irrigation in the driest areas. These graphs also give an indication of when irrigation might start to become needed. As with the SWD, there is large variability. However, on average, all but the wettest areas appear to need irrigation from sometime in November or December.

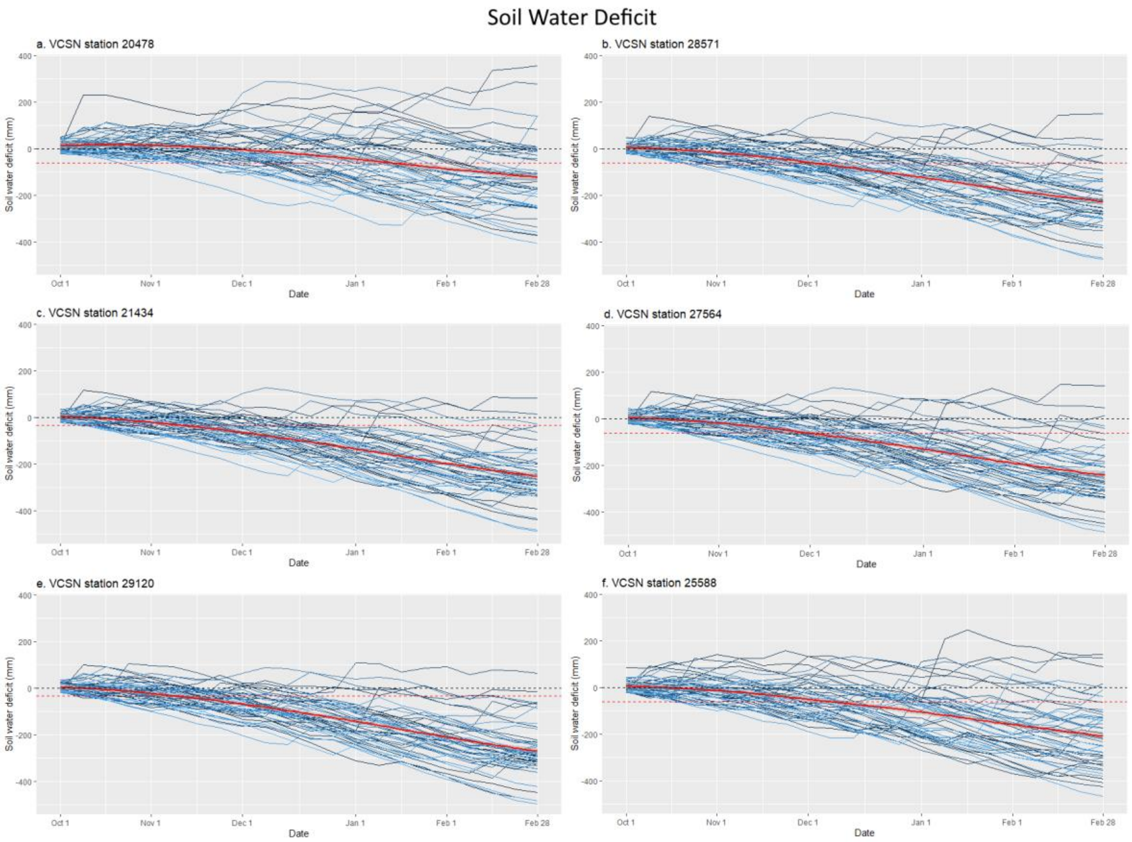

Figure 3. The October to February soil water deficit (SWD) for the six Virtual Climate Station Network (VCSN) stations analysed. The estimated readily available water (RAW) for each site is marked as the horizontal red dashed line, at -62.5 mm for graphs a, b, d, and f for VCSN stations 20478, 28571, 27564, and 25588; and -32.5 mm for c, and e for VCSN stations 21434, and 29120.

3 Sorghum

Sorghum is a genus of flowering plants in the grass family and is an indigenous crop to Africa. Traditionally sorghum was used in drought prone areas to provide better food security than could be provided by maize. The common grain sorghum (Figure 4) is ***Sorghum bicolor*** (Lynn.) Moench. This sorghum variety is used as a food crop, animal fodder, plus for alcoholic beverages and for biofuels. Danovich (2015) reported that sorghum is the fifth-most important cereal crop in the world in a provocatively entitled article in **The Guardian** on “Move over, quinoa: Sorghum is the new wonder grain”.

Figure 4. The common grain sorghum [Sorghum bicolor (L.) Moench] approaching grain maturity.

Other sorghum varieties belonging to this genus are (Gerlach and Cottier 1974):

- Sudan grass [***Sorghum sudanense*** (Piper) Hitch.] a tall tropical grass, used for hybrid breeding.
- Johnson grass [***Sorghum halepense*** (L.) Pers], a tropical grass with rhizomes that spreads rapidly.
- Columbus grass [***Sorghum almum***] a cross between cultivated sorghum and **S. halepense**.
- Sorgo, or sweet sorghum [***Sorghum vulgare* cv. *Saccharatum***], a sweet-stemmed plant used either for fodder, sugar production, or as an energy crop.

The sorghum-Sudan grass hybrid, called Sudax, or Sordan, is an interspecific hybrid that has been studied as a greenfeed stockfodder in New Zealand (Gerlach and Cottier 1974, Jurlina 1978).

Sorghum and sorghum-Sudan grass hybrids are used for green-feed fodder, and Jurlina (1978) reported that he could get three grazings from Sudax a year, with each grazing providing about 4000 kg dry matter (DM) ha^{-1}, giving an average total annual fodder yield of 10,000 kg DM ha^{-1} y^{-1} (Figure 5).

Figure 5. Break feeding of the sorghum-Sudan grass hybrid Bettagraze (Rural News Group 2014).

Grain sorghum and forage sorghums can also be used for conserved feed in the form of silage (Taylor et al. 1974)(Figure 6).

Figure 6. Field-wilted sorghum-Sudan grass being harvested for conserved feed in the form of silage.

3.1 Global production and New Zealand imports

Sorghum is an important grain crop globally. FAOSTAT (2020) reports that global grain production rose from 40 Mt y^{-1} to over 60 Mt y^{-1} between 1960 and 1980 (Figure 7). Grain production since 1980 has remained steady at around 60 Mt y^{-1}.

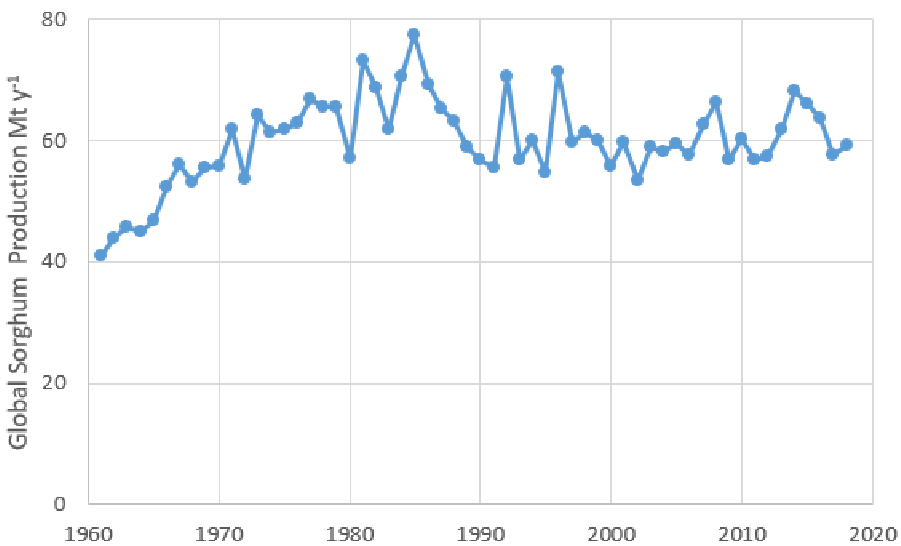

Figure 7. The global production of sorghum grain (FAOSTAT 2020).

What is interesting with the rise in global production between 1960 and 1980 is that the increase did not come from an increase in the area of land planted in sorghum, rather it was a result of an increase in sorghum productivity (Figure 8).

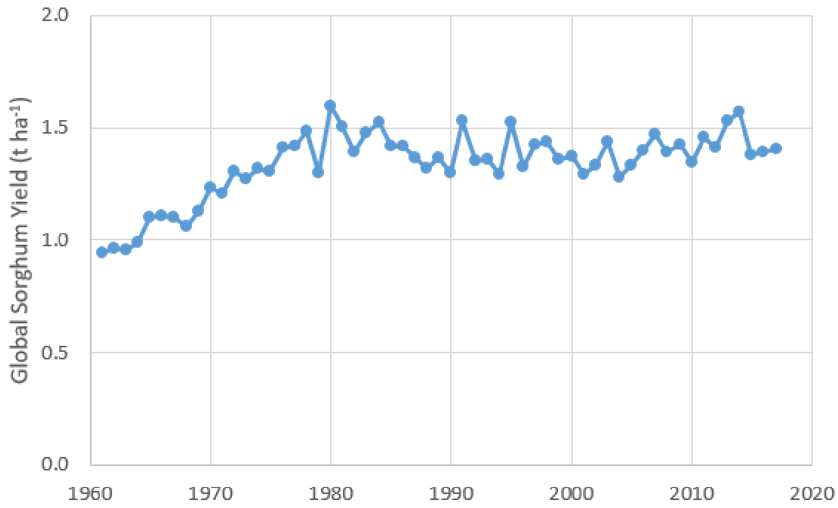

Figure 8. The global productivity of sorghum grain production (FAOSTAT 2020).

Between 1960 and 1980, the global productivity of grain sorghum rose from about 1 t ha^{-1} up to 1.5 t ha^{-1}. This rise in productivity corresponds with the Green Revolution, or the so called Third Agricultural Revolution, during which the yield of crops increased as a result of newly bred cultivars, along with better fertiliser and irrigation practices. Since 1980, however, global production of sorghum grain, and sorghum productivity have been relatively static.

Since 1980, New Zealand has imported sorghum grain, and the value of the annual quantity imported has varied greatly between years (Figure 9).

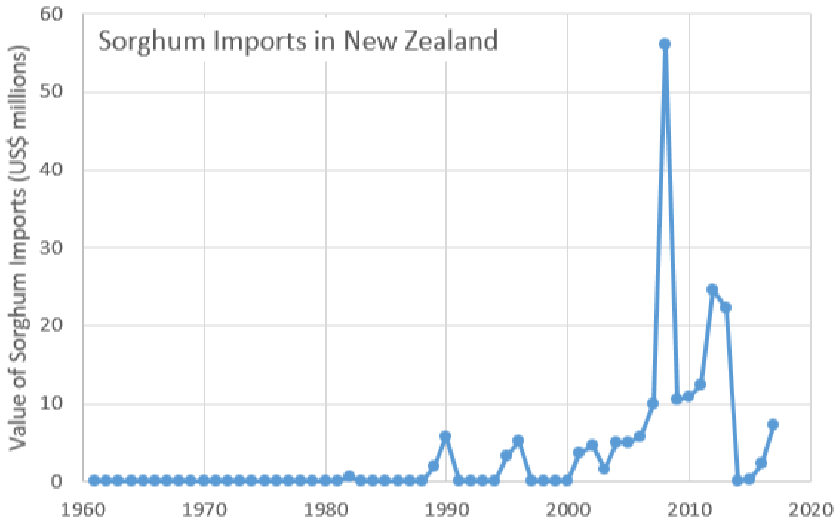

Figure 9. The value in US$ of imports of grain sorghum into New Zealand since 1960 (FAOSTAT 2020).

Millner and Roskruge (2013) considered that, as with all grain imports into New Zealand, the total imports and their value depends on domestic production, domestic demand, and the price of alternative grains. They reckoned that the 170,000 tonnes imported in 2008, at a cost of over US$ 55 million, was a result of low domestic maize production in 2007, which was down 30,000 t, combined with high international maize prices.

3.2 Sorghum in New Zealand

During the 1970s there was emerging interest in new crops for New Zealand, and a lot of this work through the (then) DSIR and the (then) MAF focussed on new cropping options for Northland, where droughts then (and now) compromise pasture production. Deeper rooting crops were seen as a better option.

This earlier research in New Zealand focussed on the use of sorghum and sorghum-Sudan grass hybrids for:

- grain production (Ryan 1975)
- greenfeed fodder (Jurlina 1978)
- conserved silage (Taylor et al. 1974)
- energy farming for ethanol (Piggot and Farrell 1980).

Despite these research ventures, FAOSTAT does not report any commercial production of sorghum ever in New Zealand. Although this is likely to be only for grain sorghum, and FAOSTAT would not necessarily capture the use of sorghum grown for greenfeed or silage. Indeed the Rural News Group (2014) report that "… the crop's been available for over a decade, but summer dries are seeing it increase in popularity, mostly north of Taupo and the odd pocket in other areas such as Hawke's Bay, and even some warmer corners of Canterbury".

3.2.1 Grain

Ryan (1975) assessed both maize and sorghum grains as being high-energy grain crops and potentially suited as stockfeeds for layer hens and broilers, as well as for pigs and stock. He noted that nutritionally maize and sorghum are similar, and he concluded that these were ideally suited for stockfeed, especially in the warmer parts of the North Island. Taylor et al. (1974) carried out trials with sorghum at three sites in Northland, and they presented results for grain production at two contrasting sites for five cultivars of sorghum with different maturity times (Figure 10).

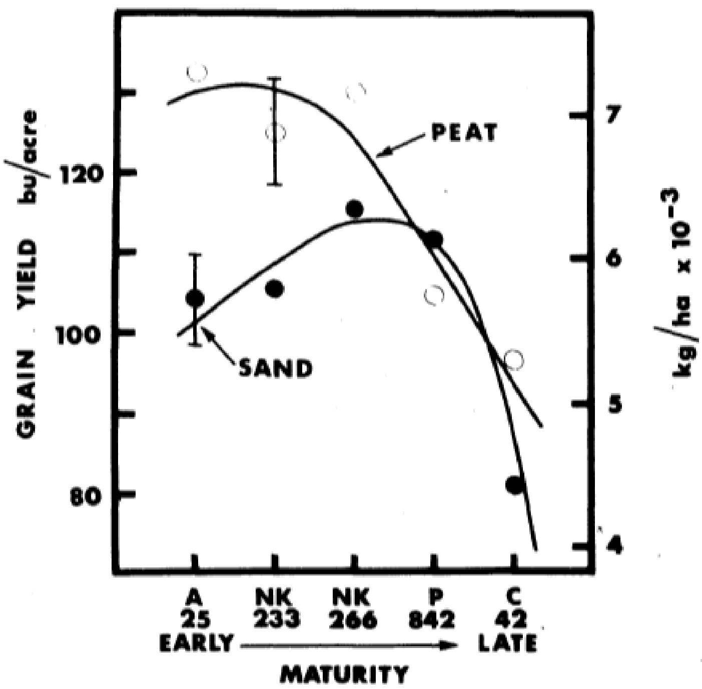

Figure 10. Interactions between varietal maturities of grain sorghum cultivars on grain yield at two contrasting sites in Northland. The sorghum was sown on 25/26 October [from Taylor et al. (1974)].

It is clear that yields on the peaty soil of around 7 t ha^{-1} exceed those on the sandy soil, which peak at just 6 t ha^{-1}. The impact of late season droughts can be seen to reduce the yields of late-season maturing cultivars. Taylor et al. (1974) conclude that "… we do not envisage that sorghum would be grown for grain in Northland, because grain yields of maize on more favoured cropping sites are potentially higher and more profitable". Millner and Roskruge (2013) report that the average maize production for the whole of New Zealand was 11 t ha^{-1} in 2012.

3.2.2 Greenfeed

Gerlach and Cottier (1974) reported that all the sorghum cultivars and sorghum-Sudan grass hybrids they tested were capable of regrowth following cutting, or grazing. They also noted that in certain circumstances Sugar sorghum could out-yield maize in terms of total dry matter. They did caution, however, that there had been cattle deaths in New Zealand attributed to grazing of sorghum during the early stages of growth when it is growing rapidly, as a result of high dhurrin concentrations in the leaves. Dhurrin is a cyanogenic glucoside which on hydrolysis in the rumen produces toxic hydrogen cyanide. They concluded that Sudan grasses and sorghum/Sudan grass hybrids are useful greenfeed crops for areas with warm summers in regions where dry periods can curtail pasture production. They did add that the total production of a full season's growth is generally out-yielded by maize. This does not agree with the results of Taylor et al. (1974), and that will be discussed later.

Jurlina (1978) found that the regrowth rate of Sudax enabled three grazings to be made. He also added that when sub-clover (*Trifolium subterraneum* cv. Woogenellup) was included in a rotation with Sudax that soil structure improved, and that producing a new seedbed for Sudax was much easier than before.

3.2.3 Silage

Taylor et al. (1974) considered that "… the main use envisaged for sorghums in Northland is production of stored feed as silage rather than for grain." They added that the total dry matter yields were "… most encouraging considering the very dry 1973–74 summer."

Taylor et al. (1974) carried out growth trails on two soils in Northland during the 1973–74 summer. One soil was a sand near Houhora, and the other a peat near Awanui. They planted five hybrid grain sorghum cultivars of varying early and late maturities, along with six hybrid forage sorghums, and two hybrid maize cultivars. The trials were planted between 24 and 26 October 1973, and harvested on 28 March 1974.

The average annual DM yield for all three crop types was 19,757 kg DM ha^{-1} on the peat, and just 11,647 kg DM ha^{-1} on the sand (Taylor et al. 1974), reflecting the impact of the dry 1973–74 summer on the crop performance on soils with the lower water holding capacity. Most of the soils of the lands identified as being suitable for arable cropping (Figure 1) have RAW in the Low (25–50 mm) and Moderate (50–75 mm) classes, so care will be needed. These include the flat lands between Ruawai and Dargaville, as well as parts of the Pouto Peninsula. Nonetheless, even a yield of nearly 12 T ha^{-1} over summer would be greater than that of a shallow rooted pasture.

The grain sorghums growing on the peat in Taylor et al. (1974) averaged 15,772 kg DM ha^{-1}, whereas the forage sorghums averaged 22,726 kg DM ha^{-1}. The maize cultivars averaged 22,295 kg DM ha^{-1}. On the sand, the grain sorghums averaged 13,018 kg DM ha^{-1}, and the mean of the forage sorghums was 10,312 kg DM ha^{-1}. The mean of the two maize cultivars was 11,555 kg DM ha^{-1}.

So for soils with higher available water holding capacities (AWC), the yield of forage crops will be higher than that on soils with lower AWCs. For soils with high AWCs, the maize and forage sorghums yield were similar, and higher than the grain sorghums. The reverse held on the sand, where the grain sorghums out-yielded the forage sorghums and maize cultivars. Since maize and sorghum, plus other crops, can be used in rotations to improve soil health, and to reduce pest and disease pressures, options exist to improve the resilience of the production of forages.

As we discuss again later, sorghum can also be used in rotation with sweet potatoes (Low 2000), as well as with soybeans (NCARS 1995). Thus sorghum, and soybeans, could well be used across the Kaipara District in rotation with themselves, as well as with pasture and kumara.

3.2.4 Energy crops

During the late 1970s energy farming for ethanol gained considerable interest. With the feed-food dilemma today, and the rise in electric vehicles, interest in farming energy crops is waning. However, Sudax and in particular Sweet sorghum cv. 'Sugar Drip', or 'Saccaline', were seen as good options for energy crops, especially in Northland. Piggot and Farrell (1980) described a trail at six sites in the north with 'Saccaline', and they compared these results with a trial at Pukekohe on two sugar beet cultivars and two fodder beet cultivars. The 'Saccaline' was planted during the last fortnight of November 1979. The sorghum reached the hard dough stage in early May. The 'Saccaline' averaged 20.3 t DM ha^{-1}, and the Sudax 15 t DM ha^{-1}. The beets averaged a sugar yield of 14 t ha^{-1}, whereas the 'Saccaline' produced only about 4 t ha^{-1} of sugar. Nonetheless, the DM results from Piggot and Farrell (1980) highlight the high yields possible with Sudax and 'Saccaline'.

3.3 Summary

From field trials carried out in 1970–80s it was shown that sorghum can be grown successfully for greenfeed and silage in Northland, and that it can provide more feed than that which can be expected from pasture during dry summers. Nonetheless, the production of sorghum can itself be affected by droughts, and soils with greater water holding capacities (Figure 2) will provide better yields. Growing sorghum for grain is possible, especially for early maturity cultivars, although the yields tend to be less than that likely to be achieved with maize. In Section 6, we provide more details about likely planting and harvest dates of sorghum cultivars across the six VCSN sites of Kaipara District.

4 Soybeans

Soybean, sometimes called soya bean, (*Glycine max* L. Merr.), is a legume that is a native of East Asia (Figure 11). Being a legume, soybeans fix atmospheric nitrogen, and this makes it a useful crop to have in a rotation with other crops. Soybeans are used in a wide variety of ways. Soybean seed contains about 20% oil, and solvent extraction is used to remove the oil, and it is then refined and ends up in many processed foods, or is used for cooking.

Soymeal, or soy oil-cake, is made from the material left after the oil extraction by solvent. It is 50% protein, and nearly all of the soymeal is used as feed for livestock feed. Indeed, soy oil-cake was the fifth-most import, by value, of food and feed into New Zealand in 2018 (FAOSTAT 2020). Of course, soybeans themselves are used as food for human consumption. The beans can be eaten with minimal processing, such as with the Japanese delicacy of edamame. Other soybean products include soy milk, soymeal, soy-flour, textured vegetable protein, lecithin, tofu, tempeh, soy-nut butter, and sweetened soybean paste.

Figure 11. Left. A field crop of soybean. Centre. Soybean pods nearing maturity. Right. Soy beans.

4.1 Global production and New Zealand imports

The website Statista (https://www.statista.com/statistics/267271/worldwide-oilseed-production-since-2008/#statisticContainer) reports that in 2019/20 soybeans were the world's largest oil-seed crop, at 337 Mt. Other oil-seed crops were, in production order, rapeseed (68 Mt), sunflower-seed (53 Mt), and then peanuts (46 Mt).

In 2017, the world's leading producer of soybeans was the United States of America (120 Mt), then Brazil (115 Mt) followed by Argentina (55 Mt) and China (13 Mt) (FAOSTAT 2020). The US National Agricultural Statistics Board reported in 2013 the 95% of the US soybean crop was genetically modified to render it glyphosate resistant, *inter alia*.

The recent trend in the global annual production of soybeans in presented in Figure 12. There has been a steady rise in soybean production since 1980.

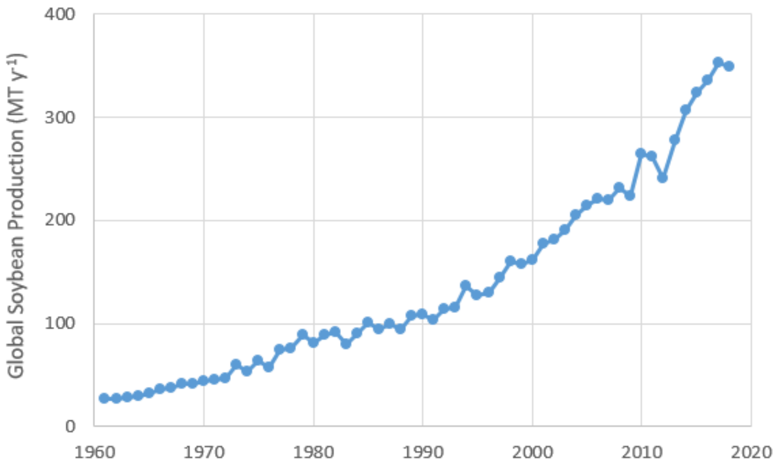

Figure 12. The rise in the annual production of soybeans globally (FAOSTAT 2020).

This production rise is a result of two factors. The harvested area of soybeans has risen fivefold from 24 M ha in 1960, through to 125 M ha in 2018. As well, the productivity of soybean farming has risen nearly threefold to reach almost 3 t ha^{-1} (Figure 13) through the use of better cultivars, and improved farming practices that maintain soil health, such as the use of minimum tillage.

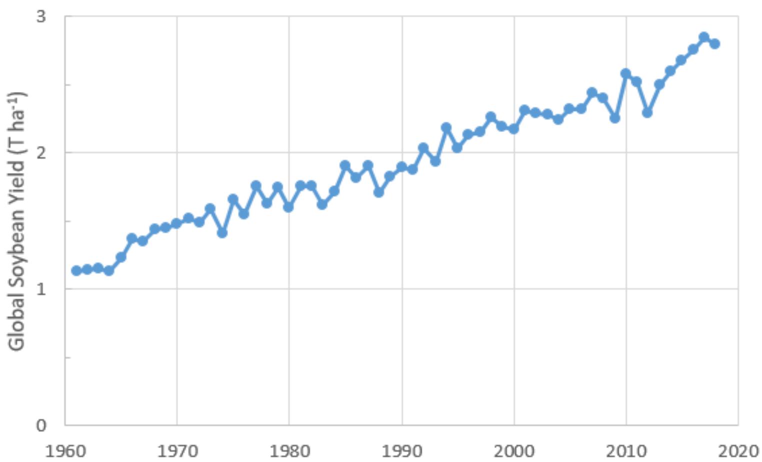

Figure 13. The rise in global productivity of soybean farming (FAOSTAT 2020).

In a search of the FAOSTAT database, a very small and rapidly declining amount of soybean production was recorded in New Zealand in the 1970s and 1980s (Figure 14). No data were available after 1993, presumably because there was in fact no soybean production.

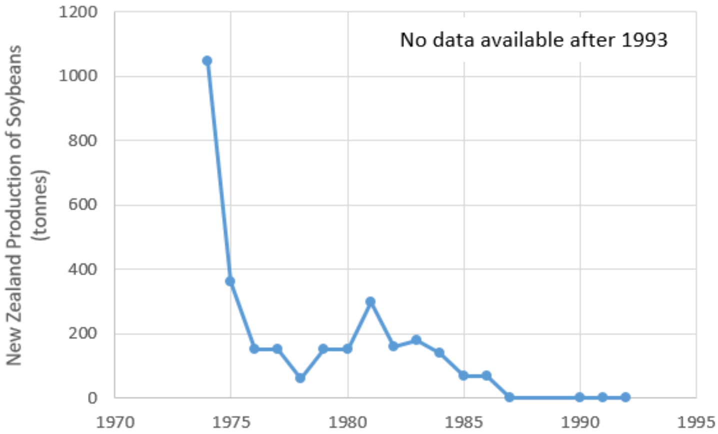

Figure 14. The decline in soybean in New Zealand through the 1970s and 1980s (FAOSTAT 2020).

Despite there being now no soybean production in New Zealand, we do import large amounts of soybean products. These are shown in Figure 15. In recent years New Zealand has imported between US$80 and $100 million worth of soy oil-cake for feeding to animals. It is the sixth most valuable food import into New Zealand. This is about one third the value of the palm kernel expeller (PKE), or palm oil-cake, that is imported for animal feed, mainly on dairy farms. Indeed four of the top six food products imported into New Zealand are for feeding to animals (Coriolis 2020). About US$15–20 million worth of soybean oil is imported, along with about US$2 million worth of soybeans themselves (Figure 15).

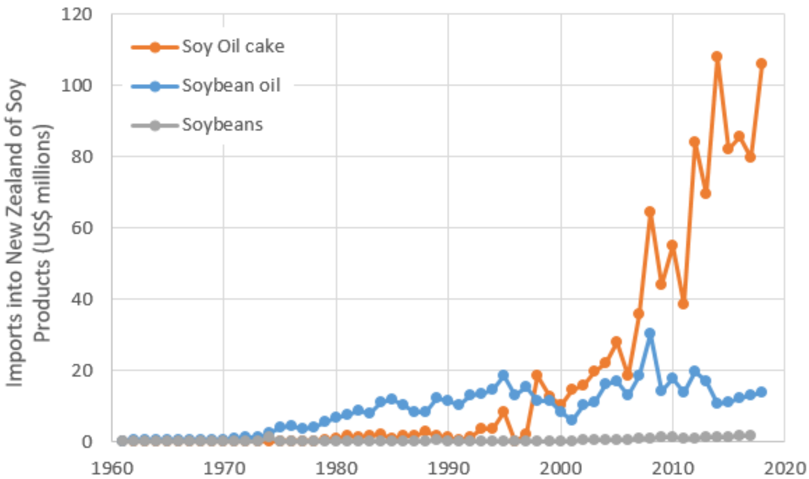

Figure 15. The value (in $US) of soybean products imported into New Zealand (FAOSTAT 2020).

4.2 Soybeans in New Zealand

Soybean growth and development is sensitive to both photoperiod and temperature. A decline in photoperiod speeds up development, whilst temperature enhances the rate of development. Cultivars of soybean are adapted to a narrow range of latitudes due to their photoperiod requirement for floral initiation. There is a cultivar classification into ten maturity groups, from 00 to 8, according to their adaptation to latitude. McCormick (1975) notes because of New Zealand's lower summer temperatures, that cultivars in classes 00 to 3 are best suited to latitudes 37–41° S, such as the Waikato. The Kaipara District extends from 35.5° S to 36.5° S.

McCormick (1974) presented results from soybean growth trials on three cultivars over five years at the Rukuhia Research Station in the Waikato. He examined the impact of six planting dates on grain yield during years with adequate rainfall (Figure 16).

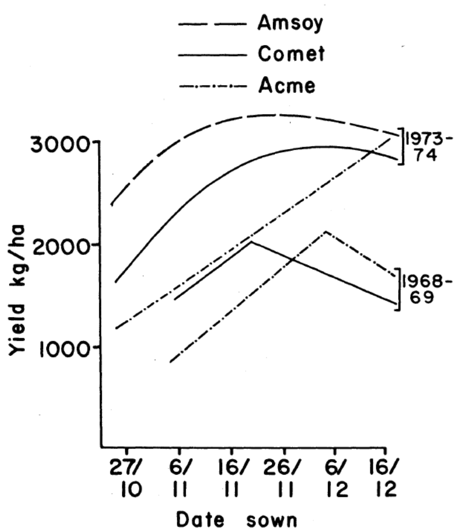

Figure 16. Soybean yield of three soybean cultivars in the Waikato during a hot season (197/74) and a cool season (1968/69) [from McCormick (1974)].

The cultivar 'Amsoy' is maturity class 2, 'Comet' is 0 and 'Acme' is 00. For the hot and dry years of 1969/70, 1970/71 and 1972/72, the yields were about one-third less (Figure 17 *cf.* Figure 16).

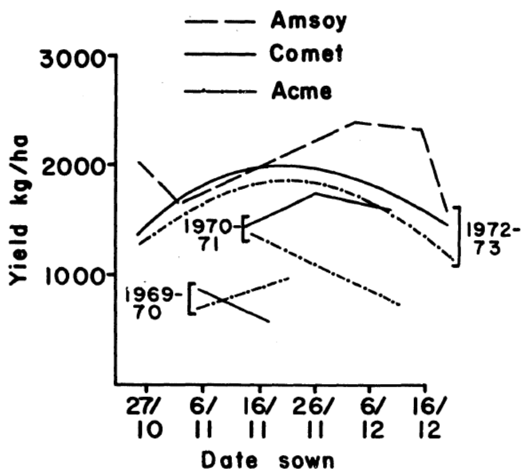

Figure 17. Soybean yield of three soybean cultivars in the Waikato during the dry years of 1969/70, 1970/71 and 1972/73 [from McCormick (1974)].

The impact of planting date in the Waikato on the performance of soybean cultivars in maturity classes 2, 3 and 4 was assessed by McCormick (1976). He found that in the Waikato that class 2 'Amsoy' increased in yield with a delay in planting date through until 26 November. The yield from the class 3 cultivars was at a maximum with an early November sowing date. McCormick (1976) did conclude that a mid-October planting did have the advantage of an earlier maturity date and more reliable harvest conditions.

McCormick and Anderson (1981) extended this soybean work between 1977 and 1980 across 11 trials with 15 cultivars. They referenced their production results to the grain yield of 3.01 t ha^{-1} from 'Amsoy'. The relative yields ranged from 74% up to 113%. The relative yield was, on average across all cultivars, 89% of that of 'Amsoy'.

Piggot et al. (1980) carried out soybean trials on three cultivars at four sites in Northland: Dairy Flat, Helensville, Otakanini (on the south shore of Kaipara Harbour), and Ruatangata (northwest of Whangarei). The cultivar 'Amsoy' produced the best yields. In 1976–77, 'Amsoy' produced 2.5 and 2.6 t ha^{-1} at Otakanini and Helensville. Over the years 1978/79 and 1979/80 it yielded 6.2 and 5.0 t ha^{-1} at Otakanini. The yields from planting earlier than 10 November were the same as those planted 1 to 2 weeks later.

Turnbull (1976) in a paper entitled "Soybean – A new crop for the Kaipara District" described trials near Helensville with 20 soybean cultivars. She found the average soybean yield to be 2.23 t ha^{-1}, with the four 'Amsoy' hybrids yielding 2.73 t ha^{-1}. In her study, there was unseasonal wet weather during October, so the planting dates were delayed until early November. Turnbull (1976) concluded that to provide financial returns that would be competitive with local maize crops yielding 6–8,000 kg ha^{-1} of grain, soybeans would need to yield between 2000 and 2750 t ha^{-1}. She concluded that "… on this basis 12 cultivars had the yielding ability to give equal or better returns than the average maize crop grown in Kaipara this season".

More recently, Millner and Roskruge (2013) found there to be "negligible production in New Zealand [as soybeans'] thermal time requirements mean that they are a marginal crop in most regions of New Zealand". We will examine this specifically in Section 6 for Kaipara District. Millner and Roskruge (2013) went on to say that yields from recent trials by the Foundation for

Arable Research have ranged from 2 to 6 t ha^{-1}, which they considered insufficient to make soybeans an economically viable crop.

Nonetheless, soybeans could provide a useful rotation crop in Kaipara District to be used in conjunction with pasture, sorghum, kumara, and possibly even peanuts. NCARS (1995) noted that when soybeans were rotated with grain sorghum, the yields of soybean were increased by 52%. The yield of soybeans grown after 3 years of fescue pasture were increased by 68%. The positive rotation effects on soybean yield were attributed to the reduction in soybean cyst nematode populations.

Given the high proportion of modern soybean seed-lines that are genetically modified, judicious choice of cultivar would be needed, and care would be needed to select locations with the best climate, as we discuss later (Section 6). We consider that for Northland an early to mid-October planting date is possible, heavy rainfalls notwithstanding.

5 Peanuts

Peanuts (*Arachis hypogaea* L.), also known as groundnuts, are a leguminous crop growing mainly for their edible seeds. Although not botanically a true nut, peanuts are commonly referred to as nuts (Figure 18). The botanist Carl Linnaeus named the species *hypogaea*, which means 'under the earth' as the peanut pods develop underground.

The seed has a high oil content of between 44 and 52%. Peanuts grow best in light sandy loam soils, and being a legume they require little nitrogenous fertiliser. Peanuts therefore work well in a rotation sequence with other crops.

Figure 18. Left. A field of a nearly mature peanut crop. Centre. Harvested peanuts showing the pods and the attached pegs. Right. Processed peanuts.

Peanuts are consumed as whole peanuts, or pressed for oil, as well as being used to make peanut butter and peanut flour. A by-product of oil pressing is the residue, which is pressed into a protein cake that is used as an animal feed, or even fertiliser.

5.1 Historical peanut production in New Zealand

Peanuts had been grown in New Zealand in the 1980s as small-scale crops across the country in areas with warm climates. This included Northland, the Hawke's Bay and Marlborough. These crops were typically less than one hectare in size, and the main reason that these operations no longer run is that the labour requirements for harvesting were too large to enable expansion. Harvesting peanuts by hand becomes impractical for crops over about a hectare, yet mechanised harvesting equipment for peanuts was not available in New Zealand in the 1980s (Anderson 1991). Nowadays, this limitation should not be as much of an issue as mechanised harvesting equipment will be easier to obtain.

Yields of up to four tonnes per hectare have been achieved, although yields of between 2 and 2.5 t/ha are more typical, depending on variety. Some crops produced very low yields, but the most common factor for that had been poor crop management, in particular poor weed control. The most successful cultivars were various Spanish and Valencia type peanuts. Late-maturing Virginia types have typically been lower-yielding under New Zealand conditions (Anderson and Piggot 1981).

5.2 Global production and New Zealand imports

In 2018, the global production of peanuts was 46 Mt. The database FAOSTAT reveals that China is the world's leading producer of peanuts with a production in 2017 of 17.1 Mt, followed by India (9.2 Mt) and the United States (3.3 Mt). The recent trend in global peanut production is shown in Figure 19.

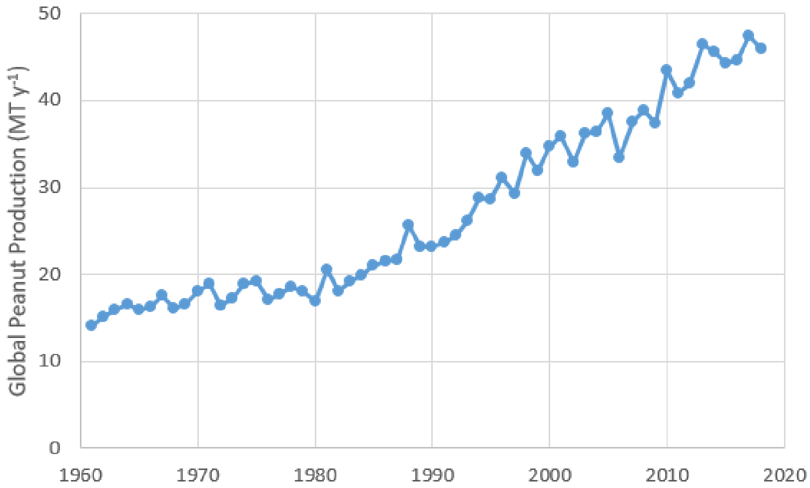

Figure 19. The rise in the global production of peanuts (FAOSTAT 2020).

This rise is, as with soybeans (above), due to two factors. The global area of land growing peanuts has increased by 70% over the last 60 years, rising from 17 Mha in 1961, to 29 Mha in 2018. As well, there has been a doubling of peanut productivity (Figure 20) with the productivity currently standing at 1.6 t ha^{-1}.

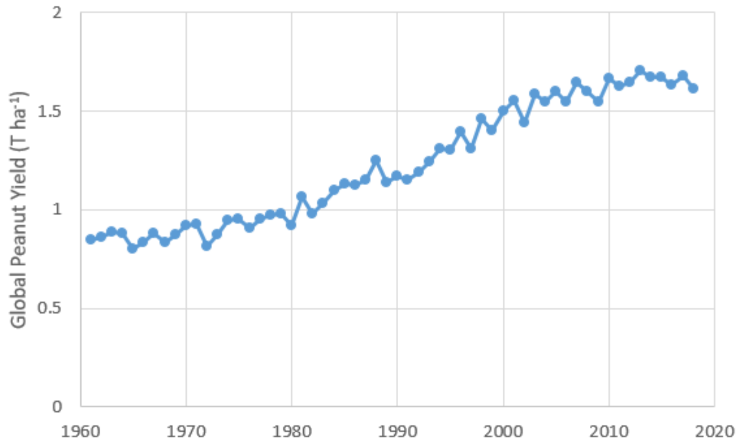

Figure 20. The rise in the global productivity of peanut farming (FAOSTAT 2020).

In 2017, New Zealand imported 11,000 tonnes of prepared peanuts, worth US$22 million. As well, there were imports of 4000 tonnes of shelled, unroasted peanuts valued at US$8 million, US$18 million worth of peanut butter, and US$1 million of peanut oil. Thus the total value of imported peanuts, or peanut products, into New Zealand is around US$50 million.

5.3 Peanut suitability

The most important requirement for peanuts to grow is sufficiently warm temperatures and, in particular, warm soil temperatures, especially in spring. Seeds are typically sown when the ground temperature reaches 15°C, and they require sustained periods of at least 18°C for sufficient growth. As seen in Figure 21, on average, the soil temperature across the Kaipara district will reach 15°C in early-mid October, and stay above there until April. The soil temperature will be at or above 18°C, on average, from late November to March. Most years will have at least 1 or 2 months with sufficient soil temperatures for peanut growing, and it is rare for the soil temperature not to reach 18°C at all in a given year. This is in contrast to most of the rest of New Zealand. Hence peanuts represent a good opportunity for Kaipara, and Northland in general.

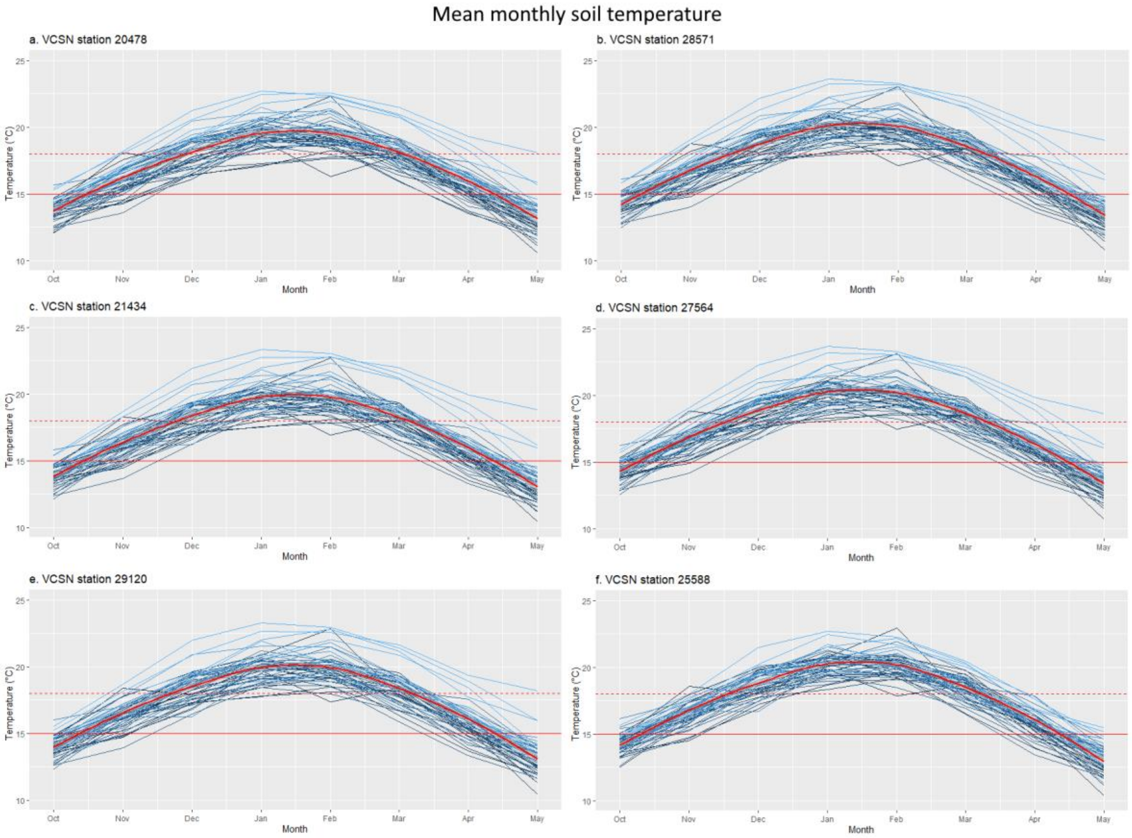

Figure 21. Mean monthly soil temperatures for the six Virtual Climate Station Network (VCSN) stations. Lines of 15°C (solid red) and 18°C (dashed red) are shown.

5.3.1 Peanuts – Recommendation

Given that peanuts require warm and free-draining soils, and relatively deep potential rooting depths, they are likely to be an agronomically feasible crop to grow in Kaipara. In particular, we believe that the Pouto Peninsula is a likely candidate for peanut cultivation since the free-draining, sandy soils are common there, and they would likely be suitable for peanuts. However, since the Pouto Peninsula is susceptible to erosion, measures to mitigate or protect from wind erosion would likely be needed.

6 Potential for Kaipara

To provide additional agronomic insights into the potential for the arable cropping of sorghum, soybeans and peanuts, we have used the weather data from the six representative VCSN stations to examine the likely best sowing dates, and to predict the grain harvest dates for cultivars of different maturity cultivars.

6.1 Sowing dates

All three crops require, we consider, the soil temperature at 10 cm, T_{soil} (°C), to be above 15°C to ensure successful seed germination. For the six VCSN stations identified in Figure 1, we present below in Table 2 the date at which T_{soil} exceeds 15°C.

Table 2. The date of the first day when the soil temperature at 10 cm, T_{soil} (°C), exceeds 15°C for six Virtual Climate Station Network (VCSN) sites in Kaipara District.

Seed germination	Waipoua VCSN20478	Te Kopuru VCSN21434	Ruawai VCSN27564	Dargaville VCSN28571	Pouto VCSN29120	Mangawhai VCSN25588
First day T_{soil} >15°C	6 October	7 October	30 September	2 October	6 October	2 October

Thus for all crops the earliest planting date, in terms of soil temperature, would on average be around 1 October. The local pattern of rainfall and soil water conditions would, of course, alter the specific timing and ability to plants these crops during the first week of October in any given year.

6.2 Sorghum

Cultivars of grain sorghum have a wide range of seasonal maturities. Parthasarathi et al. (2013) reviewed the impact of the crop heat-units of growing degree days, base 10°C (GDD_{10}), on crop production and the timing of grain maturity. They considered sorghum requires, in general, a GDD_{10} of 1415 degree days. Neild and Seeley (1977) found that some Nebraskan short-season sorghum hybrids might only need 1250 degree days. Gerik et al. (2003) considered that short-season sorghum cultivars would require a GDD_{10} of about 1485 growing degree days to reach full maturity. They also found that long-season cultivars can require a seasonal GGD_{10} of 1867 to reach grain maturity. We will use these values of GGD_{10} of 1485 and 1867 to assess conservatively the likelihood of grain sorghums reaching maturity in the Kaipara District. We have calculated the GDD_{10} values, accumulated after 1 October, for the six VCSN stations across Kaipara District shown in Figure 1. As well, we provide a risk assessment of the likelihood of a sorghum crop reaching grain maturity over summer (Table 3).

Table 3. Predictions of the mean season length (d) and mean harvest date of a short-season sorghum cultivar (top) and a long-season cultivar (bottom) growing in the Kaipara District near six virtual climate station network sites (VCSN). The planting date was assumed to be 1 October. Also given are the percentage of the years, in the VCSN record of 46 years, in which the respective GDD_{10} criteria would be realised.

Sorghum	Waipoua VCSN20478	Te Kopuru VCSN21434	Ruawai VCSN27564	Dargaville VCSN28571	Pouto VCSN29120	Mangawhai VCSN25588
Short-season cultivar						
Mean season length (d)	209	205	197	200	204	198
Mean harvest date	1 May	27 April	16 April	19 April	26 April	18 April
Years with GDD_{10}	83%	75%	95%	95%	85%	95%
Long-season cultivar						
Mean season length (d)	247	247	250	253	246	250
Mean harvest date	22 May	23 May	29 May	31 May	24 May	1 June
Years with GDD10	10%	10%	37%	31%	12%	35%

A short-season sorghum cultivar would have a growing season of about 200–210 days, with a harvest day of mid to late-April, depending on location. Except for Te Kopuru, some 85%, or more, of years would enable a short-season cultivar to reach maturity.

A long-season cultivar would have a growing season of around 250 days, and could be harvested in mid to late May. However, only between 10 and 35% of years would have sufficient warmth for the crop to reach grain maturity.

So if sorghum were to be grown for grain, cultivar selection, and choice of location would be important. Taylor et al. (1974) did note that growing sorghum for grain, given the low yields they found, would not be a good option, especially in relation to the grain yields that are likely from maize.

Thus the focus for sorghum growing in Kaipara might best be on its use as a drought-resistant green-feed, or silage (Taylor et al. 1974, Jurlina 1978).

6.3 Soybeans

Kausik et al. (2015) studied the impact of sowing date and seasonal warmth on the time for three soybean cultivars to reach grain maturity. Their GDD_{10} values ranged from 1450 through to 1900 degree days. Bhan et al. (2019) also studied three soybean cultivars and found the time to maturity ranged between GDD_{10} values of 1283 and 1629 degree days. We take this range here for our assessment of season length and harvest dates for soybeans that could be grown in the Kaipara District (Table 4).

Table 4. Predictions of the mean season length (d) and mean harvest date of a short-season soybean cultivar (top) and a long-season cultivar (bottom) growing in the Kaipara District near six virtual climate station network sites (VCSN). The planting date was assumed to be 1 October. Also given are the percentage of the years, in the VCSN record of 46 years, in which the respective GDD_{10} criteria would be realised.

Soybean	Waipoua VCSN20478	Te Kopuru VCSN21434	Ruawai VCSN27564	Dargaville CSN28571	Pouto VCSN29120	Mangawhai VCSN25588
Short-season cultivar GDD_{10} = 1283						
Mean season length (d)	179	179	168	170	174	169
Mean harvest date	3 April	4 April	18 March	21 March	30 March	21 March
Years with GDD_{10}	97%	97%	97%	97%	97%	97%
Long-season cultivar GDD_{10} = 1629						
Mean season length (d)	231	228	215	219	225	218
Mean harvest date	19 May	15 May	1 May	4 May	13 May	6 May
Years with GDD_{10}	56%	50%	79%	75%	60%	83%

A short-season soybean cultivar will have season lengths varying between about 170 and 180 days with harvest dates from mid-March until early April. Virtually all years will enable short-season cultivars to reach grain maturity.

Long-season cultivars will have growing seasons between 215 and 230 days, with harvest dates being from early to mid-May. Between 50 and 80% of years, depending on location will result in the long-season cultivars reaching maturity.

6.4 Peanuts

Canavar and Kaynak (2010) studied the GDD_{10} required for four cultivars of peanuts to reach physiological maturity, and there experiments ran over 2 years in Turkey. For their early planted peanuts, these cultivars required GDD_{10} values of between 1450 and 1600 degree days. We use these values in our assessment of the prospects for peanut growing in the Kaipara District (Table 5).

Table 5. Predictions of the mean season length (d) and mean harvest date of a short-season peanut cultivar (top) and a long-season cultivar (bottom) growing in the Kaipara District near six virtual climate station network sites (VCSN). The planting date was assumed to be 1 October. Also given are the percentage of the years, in the VCSN record of 46 years, in which the respective GDD_{10} criteria would be realised.

Peanuts	Waipoua VCSN20478	Te Kopuru VCSN21434	Ruawai VCSN27564	Dargaville VCSN28571	Pouto VCSN29120	Mangawhai VCSN25588
Short-season cultivar GDD_{10} = 1450						
Mean season length (d)	204	203	191	194	198	192
Mean harvest date	26 April	26 April	9 April	14 April	21 April	12 April
Years with GDD_{10}	87%	83%	95%	95%	87%	95%
Long-season cultivar GDD_{10} = 1600						
Mean season length (d)	225	224	215	213	223	213
Mean harvest date	13 May	13 May	2 May	30 April	13 May	2 May
Years with GDD_{10}	60%	56%	87%	77%	70%	85%

A short-season peanut cultivar will have growing season lengths of between 190 and 205 days, depending on location with Kaipara District, and the harvest dates will be between early and late April. Some 85 to 95% of years will enable the peanuts to reach harvestable maturity.

For a longer-season peanut cultivar the growing season length will be between 215 and 225 days, with harvesting between late April and mid-May. Some 55–90% of years will enable a long season cultivar to reach maturity.

These analyses show that selection of the peanut cultivar, and the choice of location to grow it, will be critical for successful peanut production. We are presently embarking of an SFFF programme of field research with a range of peanut cultivars that will enable us to determine GDD_{10} requirements so that we can refine our ability to match cultivar with location.

7 Conclusions

We have carried out an assessment of the suitability across the Kaipara District for the arable cropping of sorghum, soybeans and peanuts. These crops present an opportunity to be incorporated into cropping rotations with existing agricultural systems in the Kaipara District. For all crops, matching cultivar selection to location will be important to ensure the local weather and soil conditions are appropriate.

It is likely that peanuts would be best suited to the sandy soils in the west of Kaipara District, especially on the Pouto Peninsula, whereas soybeans and sorghum would be better suited to the heavier textured soils surrounding the Kaipara Harbour and Ruawai, plus those in the east towards Mangawhai. Choice of soybean and sorghum cultivar will be critical to ensure that the crop can reach grain maturity. Sorghum could also be used as a greenfeed crop, or grown for conserved feed in the form of silage.

We have presented details as to the locations where we consider these crops could be grown, and the likely impact of droughts on crop production. We have also quantified the likelihood of these crops reaching grain maturity as a function of location and season-length cultivars.

In our next report, we will provide an assessment of the likely impacts of climate change on our assessments for the six crops we have considered. We will use the various RCP (Representative Concentration Pathway) climate-change projections for the six VCSN stations that we have been provided by NIWA.

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