# Hazelnut Production:
# Potential for the Lake Taupo catchment

Looking over land suitable for growing hazelnuts from Karangahape Road, Lake Taupo

**Prepared for the Lake Taupo Protection Trust and the Waikato Branch of New Zealand Tree Crops Association**

**Murray Redpath, Wairata Forest Farm**

**January 2012**

Lake Taupo Protection Trust
Te wai, te iwi

Waikato Branch, NZ Tree Crops Association Inc.

## Acknowledgements

This project was funded by the Lake Taupo Protection Trust and the Waikato Branch of the New Zealand Tree Crops Association. The Waikato Regional Council assisted with the provision of Land Use Capability information for the Lake Taupo catchment.

I would like to thank the owners of the two orchards, Eric and Vicky Evans, and Len and Helen Cosh, for providing the use of their orchards.

Valuable assistance with land use information was provided by Jon Palmer and Howard Ettema from the Waikato Regional Council. Kevin Snowden provided background to previous work on identifying alternative crops for the Lake Taupo catchment by the Lake Taupo Development Company.

The important role of Maurice Denton, Waikato Tree Cropper, who initiated this project in the belief that it could offer Taupo farmers new economically viable land use options, is acknowledged.

## Contents



## Tables and Figures

# Hazelnut Production: Potential for the Lake Taupo catchment

## Executive Summary

The Waikato Regional Council has introduced controls on nitrogen leaching from land in the Lake Taupo catchment in an attempt to reduce the rise in nitrogen levels in the lake waters. To increase returns, Taupo landowners need to find alternative land uses that yield low levels of leached nitrogen while returning profits comparable to or greater than traditional farming systems. Experience in New Zealand indicates that hazels grow and crop well in many areas, including areas such as Southland which have cold climatic conditions, and may offer an alternative economic land use for land in the Lake Taupo catchment. The performance of several small hazelnut orchards in the Waikato and Bay of Plenty areas planted by members of the New Zealand Tree Crops Association (NZTCA) indicated that hazels should grow well in the Taupo region. The Waikato branch of NZTCA initiated this report to investigate whether commercial hazelnut production could offer an alternative economical land use for Taupo landowners.

This study searched available literature and internet sources for information on the climate of the Taupo region, the nitrogen requirements for commercial hazelnut orchards, and hazelnut market characteristics. Land use capability information made available by the Waikato Regional Council was used to identify the areas of land suitable for commercial hazelnut production and to calculate the area available.

Two small hazelnut orchards in the Taupo region were used to examine the growth rates and nut quality of hazelnuts grown in the area. Growth rates and general tree health of the hazel trees in these orchards showed that hazels are well adapted to the Taupo climate. Yields observed in the orchard at Turangi indicated that yields comparable with those achieved elsewhere in New Zealand are possible in the Taupo region.

The nuts from the 2011 harvest had high levels of mouldy kernels from those varieties known to be susceptible to mould. It is recommended that varieties selected for planting on the western side of the Lake Taupo catchment should have a low susceptibility to mould. Further research is needed to determine the quality of nuts from varieties susceptible to mould when grown on the drier eastern side of the Lake.

The climate of most of the Lake Taupo catchment is suitable for commercial hazelnut production. Comparisons with climatic data from a well established orchard at Wairata in the eastern Bay of Plenty, and similarities in the quality of nuts from Turangi and Wairata indicate that nut quality information from the Wairata orchard could be used to select varieties suitable for the Taupo region.

Approximately 4800 hectares of Class 3 land, currently in pasture, could be considered as having good potential for commercial hazelnut production with only slight or moderate limitations to economic development. There are also a further 4300 hectares of Class 3 land suitable for growing hazels that may have economic limitations to profitable hazelnut production either because the land is planted in exotic forests, is located on the western edge of the catchment isolated from other potential growing areas, or has potential for subdivision for urban or peri-urban development.

European studies suggest that hazelnut growing with commercially acceptable yields should be possible with nitrogen fertilizer applications containing up to 75 kg per hectare of nitrogen. At this rate of nitrogen application, hazelnut production would be a permitted activity under the Section 5 rules implemented by the Waikato Regional Council. These rules assume that applying 75 kg N/ha results in a leaching rate leaching of 8 kg N/ha/year. The optimum time for applying nitrogen in hazelnut orchards is during the period of rapid vegetative growth in the spring. Research is required to establish the true N leaching rate from hazelnut orchards.

The gross margin for hazelnut production in the Lake Taupo catchment is estimated at about $4800 per hectare, assuming that production levels and processing costs are similar to those achieved in Oregon, USA, and a price of $3/kg. This is similar to estimated returns for hazelnut production in Australia, Oregon, and Italy. If these returns can be achieved, they exceed the gross margins from most livestock based farming systems and are significantly higher per kilogram of leached nitrogen. Costs of harvesting and processing the hazelnuts ready for sale are uncertain as the facilities do not exist in the North Island at present. It is possible that gross margins could range from less than $2500/ha (small scale, inefficient harvesting/processing systems) to more than $8500/ha (efficient harvesting/processing systems, new productive varieties).

While the area of hazels already planted in New Zealand has the ability to supply the current New Zealand consumption of hazelnuts, potential export markets exist, including Australia (for example, supply to the Ferrero factory there) and China. The Chinese market, which buys mainly in-shell hazelnuts, offers potential for areas like Taupo that do not yet have easy access to existing nut cracking facilities.

If landowners with land suitable for commercial hazelnut growing in the Lake Taupo area decide to plant hazelnuts, the following research is recommended.

1: Hazelnut markets in Australia and China should be investigated to determine the characteristics of these markets, the nut quality required, and any opportunities for supply by New Zealand hazelnuts.

2: Trials should be established to determine the varieties most suited to the Lake Taupo catchment. These trials should compare productivity (yield and yield efficiency) and nut quality. Varieties trialed should include Barcelona, Ennis, Lansing and Jefferson for the Chinese in-shell market and Tonda di Giffoni, Tonda Romana, Tonda Gentile delle Langhe, Appleby, and Whiteheart for kernel markets.
Nut quality assessments could start immediately using nuts from the Turangi orchard, supplemented with nuts from the Wairata Forest Farm Variety Collection.

3. New trials could also include plots examining the nitrogen leaching characteristics of hazelnut orchards. These plots could be used to examine the efficiency of various forms of nitrogen fertilizer and the yield response to various application rates to determine the optimum application rates.

4. The trials should test the effect of irrigation on yields on the main soil types planted to determine the requirements for orchards on the pumice soils.

5. Research is required to determine the best species mix for the orchard floor taking into account the requirements for harvesting and control of soil erosion.

6. If landowners wish to integrate livestock grazing or irrigate with effluent, research will be required to determine whether levels of coliform bacteria at harvest can be maintained at acceptable levels.

Results from any research into hazelnut growing will be applicable to the wider Volcanic Plateau region.

## Introduction

Evidence of deterioration in the water quality of Lake Taupo, primarily from nitrogen enrichment of the lake water, has resulted in regulation of land use within the Lake Taupo catchment. Regulations were introduced by the Waikato Regional Council with the aim of reducing the nitrogen inputs into the lake by 20%. These regulations place a nitrogen "cap" on individual properties and encourage the conversion of land to uses with lower N leaching potential (Environment Waikato, 2003).

Research has shown that the main source of N leaching on pastoral farms is from stock urine patches, especially from cattle. Any attempt to cap N leaching from pastoral properties effectively places a cap on stock numbers, limiting the potential to increase production and income. The difficulties in finding options for increasing pastoral farm incomes while restricting N leaching were highlighted by Thorrold and Betteridge (2006).

Alternative land use options for pastoral land in the Lake Taupo catchment require crops that are tolerant of cold winters and out of season frosts, capable of ripening a crop in the short growing season with maximum utilization and minimal leaching of any applied nitrogen. Alternative land uses should also have gross margins equal to or higher than those of existing land uses.

The European hazel, Corylus avellana, is adapted to a cool temperate climate and is tolerant of winter temperatures down to -8°C. The main hazelnut production areas in the northern hemisphere have a Mediterranean-type climate and are located in the latitude range 37° to 47° Nth. While most production areas have dry summers some large hazel growing areas have humid summers. In Georgia, for example, the main hazelnut growing region lies in the west adjacent to the Black Sea with a humid subtropical climate) where citrus and tea were also grown (Mehlenbacher, 2002).

Experience in New Zealand indicates that hazels grow and crop well in many areas, including areas such as Southland which have cold climatic conditions. Research into hazelnut production in New Zealand has been carried out in Nelson and Canterbury in soils and climates that differ significantly from the Taupo region. A limited amount of unpublished data, including yields and nut quality, has been collected from the Wairata Forest Farm Hazelnut Variety Collection in the eastern Bay of Plenty. Soils in this orchard are free draining sandy loams derived from volcanic ash. Information from this orchard may be more relevant to determining potential yields and nut quality from hazelnut orchards in the Taupo catchment than the information from the Nelson and Lincoln research.

The focus of this study was:

1. To establish whether hazels will grow and crop successfully in the Taupo catchment and produce nuts of a commercially acceptable quality, using two small hazelnut orchards in the Taupo area to assess growth rates and nut quality, and climate data for the Lake Taupo catchment to determine any climatic limitations to commercial hazelnut production;

2. To establish the nitrogen requirements of commercial hazelnut orchards and ascertain whether hazelnut production would fit with the Variation 5 regulations for the Lake Taupo catchment;

3. To estimate the area of land suitable for hazelnut production within the Lake Taupo catchment;

4. To estimate the potential economic returns from growing hazelnuts in the Lake Taupo catchment.

5. To examine the New Zealand and international hazelnut markets.

# Method

## 1: Establishing whether hazels will grow and crop successfully in the Taupo catchment

**Orchard and Nut Quality Assessment**

Two small hazel orchards in the Lake Taupo area (on Poihipi Road at the junction with SH 32 and Grace Road near Turangi) were visited in December 2010 to assess tree condition and nut set, and to check for any evidence of frost damage to nut clusters. Trees were examined for bacterial blight damage. Bacterial blight is not usually a significant problem on trees older than 4 years but trees under any sort of stress are more susceptible to bacterial blight and it is a useful indicator of whether environmental conditions are suitable.

Branches (15 at Turangi, 3 at Poihipi Road) were randomly selected from throughout the orchard and tagged. Details of the number of nut clusters and nuts per cluster were recorded. These tagged branches were examined again in the first week of February, just prior to harvest, to assess any loss of the crop between fertilization and harvest. A sample of 100 ripe nuts was harvested directly off trees of two varieties, Barcelona and Tonda di Giffoni, in the Turangi orchard. These nuts were dried and the nut quality assessed to determine the quality of nuts prior to nut fall (nuts lying in damp orchard floor conditions can influence the development of mould on kernels).

A second sample of 100 nuts from all main varieties present in the Turangi orchard was harvested off the ground in at the end of February and early March (for late falling varieties) after most of the crop had fallen. This collection equates to the normal harvest time. The nut crop in the Poihipi Road orchard was very low and samples of 25 nuts were collected.

Samples of the same varieties were taken from the Wairata Forest Farm cultivar collection on the day following the collection of nuts from Turangi. Comparisons with nut quality at Wairata were made to assess whether that orchard could be used to select suitable varieties for the Taupo catchment.

All nut samples were initially air dried on racks in the sun for a week and then finished inside using a dehumidifier. Dried nuts were weighed, cracked and assessed for blank nuts and kernel faults.

Soil and leaf samples were taken from both orchards to assess the nutrient status of the soils and the trees. Samples were tested at Hill Laboratories in Hamilton.

**Assessment of the suitability of the climate of the Taupo catchment for hazelnut production**

Climate data for Taupo (Wairakei Research Station, Agent No.1846), Turangi (Turangi Ews, Agent No's 2347/12432) and Wairata (Agent No.1916) was downloaded from the NIWA Cliflo website (http://cliflo.niwa.co.nz/). Long term temperature data does not exist for the Wairata site so temperature data from the Waimana site (Agent No.1883) has been used. Waimana has similar climatic influences to Wairata, being in an adjacent valley system with protection from coastal influences that affect other sites close to Wairata such as Opotiki.

## 2: Nitrogen requirements for hazelnut production and N restrictions in the Lake Taupo catchment

An internet search was undertaken to examine any literature in the following areas of interest:

- the background to the environmental problems associated with changes in land use in the Lake Taupo catchment and regulations to control nitrogen use in the catchment

- research into land use options for the Central North Island and the nitrogen characteristics of those land use options
- nitrogen requirements for commercial hazelnut production.

Relevant literature was checked where references were not available online.

## 3: Estimating the area of land in the Taupo catchment suitable for hazelnut production.

An internet search was carried out for information on soils and land use capability of land in the Lake Taupo catchment. Class 3 and 4 land, as defined in the NZ Land Use Capability system (Lynn et al, 2009), is considered to be suitable for growing tree crops. Maps of the Lake Taupo catchment showing the location of units of Class 3 and 4 land and the areas of these land classes, were obtained from the Waikato Regional Council. The topography of these areas was checked using Google satellite imagery on Google Maps or during visits to the catchment to examine the orchards.

The land class units were assessed for any characteristics that could limit the long term economic potential for hazelnut production. The factors considered were:

- erosion potential under conventional hazelnut orchard management
- poorly drained soils that may require drainage
- soils with excessive drainage potential (e.g. soils on deep coarse pumice) that may require irrigation
- indigenous vegetation cover (to remove units that may be reserved for conservation purposes),
- proximity to other suitable units,
- proximity to the lake edge or urban areas (to identify the potential for future urban or peri-urban development).

When considering the erosion potential, hazelnut growing was treated as an 'arable' crop with the same potential for erosion on the pumice soils as for arable crops rather than for orchard crops such as apples. Nut crops are harvested off the ground and vegetation on the orchard floors is either sprayed out or kept very short to enable efficient harvesting. Until research proves otherwise, it would be prudent to assume that the erosion potential in a hazelnut orchard would be similar to that of an arable crop. With this assumption, Class 3 land would have "moderate physical limitations" to use for hazelnut cropping and Class 4 land would have "severe physical limitations (Lynn et al, 2009).

## 4: Potential economic returns from hazelnut orchards in the Taupo catchment

Estimates of the costs and returns associated with growing hazelnuts in the Lake Taupo catchment were made using models developed by the Oregon State University (Julian et al 2008a, 2008b). Most New Zealand costs were taken from the 2010 edition of the Lincoln University Financial Budget Manual.

## 5: NZ and International hazelnut market characteristics and trends

An internet search was used to access recent information on international trends in hazelnut production and market characteristics. Further information on international trends has been sourced from discussions with industry researchers from Oregon ( Prof. J. Olsen, Oregon State University in 2008 and 2010), Australia (B. Baldwin, Charles Sturt University, 2006 and 2009), and Chile (Dr. P. Grau, 2011).

## Results and discussion

### 1: The environmental suitability of the Lake Taupo catchment for hazelnut production.

**Examination of orchards in the Lake Taupo catchment and comparison with the Wairata Forest Farm orchard**

***Poihipi Road***

The orchard on the corner of Poihipi Road and SH 32 was planted in the late 1980's, with additional recent immature plantings on an adjacent hill using rooted suckers from the larger trees. Total area is approximately 500 $m^2$. The original planting of about 50 trees has a complete canopy with very little nut production in lower parts of the canopy due to lack of light. Some removal of suckers has occurred in the past but many trees have numerous large suckers present. The orchard floor is bare soil with weak grass around the edge of the orchard.
The main variety planted is Plowright, with a mix of pollinisers (Merveille de Bollwiller, Butler, Alexandra, and a few early NZTCA selections) plus a few Whiteheart.

Approximately 40 kg of blood and bone (approx. 32kg N/ha.) plus lime have been applied most years. Soil and leaf tests showed significant deficiencies of magnesium and boron. Leaf N levels were 2.4%. This lies within the "optimal" range according to the Oregon Hazelnut Nutrient Management Guide (Olsen, 2001). Recommendations in this guide would be to apply 68 - 91 gm N/tree (296-396 kg/ha).

Annual shoot growth of 15 to 45 cm indicates good vegetative growing conditions.

Yields were low on all varieties. The main variety used, Plowright, is known to be low yielding. A low yield on the Whiteheart is to be expected in a closed canopy situation. Barcelona and Butler, usually high yielding varieties, had better crops than Whiteheart and Plowright but still well below what would be expected from those varieties, especially as the trees were on the edge of the planting and exposed to good light on one side. Hazels do develop biennial bearing patterns and 2011 was a low crop year in many orchards. Low boron levels will probably limit yields in this orchard.

***Grace Road, Turangi***

The Grace Road orchard at Turangi consists of two blocks. The larger back block was planted in 1999 and 2000. Extra trees were added in 2002. The smaller front block was planted in 2002, but has suffered severe pruning by livestock. Only the back block was used for this project. The trees in this block had suffered variable levels of browsing damage by horses. Some trees had been severely browsed and had only young growth available but approximately 60%of the trees had a reasonable production canopy.

The original owner was an organic grower who worked overseas after the trees were planted. The trees were planted with additions of compost and blood and bone to the soil. The present owners have owned the property for four years and removed suckers once soon after purchasing the property. No fertilizer has been applied but horses have been grazed between the trees and nitrogen would have been added from their urine. The orchard floor has grass right up to the trunks.

This area was mapped to identify the varieties present. The main varieties are Tonda di Giffoni, Tonda Romana, and Waihi, with a mix of pollinisers including Merveille de Bollwiller, Kentish Cob, Plowright, and Barcelona. Most trees had 15 to 30 cm of annual shoot growth on well lit, upper canopy areas, with 5 to 15 cm in the lower canopy. These rates indicate good vegetative growing conditions. Trees of Waihi on the southernmost rows showed signs of infection with bacterial blight (*Xanthomonas arboricola pv. corylina*). Waihi is known to be very susceptible to bacterial blight and this disease is most severe on stressed plants. These trees are not well sheltered from southerly winds and would be exposed to cold winds. Frost damage is also known to predispose hazels to bacterial blight.

Soil and leaf tests showed low levels of all nutrients in the soil but adequate leaf levels of all nutrients except for magnesium. Boron levels in the Turangi orchard were very high, at 83 mg/kg, despite soil levels being low. No reason for this anomaly has been identified. Leaf N levels were 2.7%. Recommendations from the Oregon Hazelnut Nutrient Management Guide (Olsen, 2001) would be to apply no nitrogen fertilizer.

Visual assessments of the yields placed the crops at 2 to 3 kg/tree for Tonda di Giffoni and Barcelona, 1 to 2 kg/tree for Tonda Romana and less than 1 kg/tree for Waihi, Kentish Cob, Merveille de Bollwiller and Plowright. For most of these varieties, yields of this magnitude would be typical of trees of this size in an unpruned state. The poor crop loading on Waihi was not typical of the performance of that variety. The low yields on Waihi may be due to blight damage but poor pollination is a more likely factor. Waihi is a late flowering variety and there is a lack of late pollen sources in this orchard.

All nut clusters on the marked branches developed fully. Branches were examined for mummified immature nut clusters (indicating damage by late frosts). Just one cluster was found, in the Turangi orchard. This was found on two year wood and would probably have been affected by the severe late frost in November 2009.

***Wairata Forest Farm Variety Collection***

The Wairata Forest Farm variety collection was planted between 1982 and 1989. Soils are mapped as Matawai sandy loam (Rijkse et al, 2010). Yield data was recorded until 1994 and showed per tree yields similar to those achieved in a trial at Lincoln University (Murdoch et al, 1995). The orchard floor varies from bare soil under a complete canopy (e.g. under the Barcelona and Whiteheart trees) to low producing mixed species pasture (with subterranean clover as the predominant legume) where there is less canopy cover due to tree removal or recent pruning (e.g. under the Tonda di Giffoni and Tonda Romana trees).

Over the last 3 years, a general horticulture fertilizer (Nitrophoska Blue TE or YaraMila Complex) has been broadcast in November applying approximately 46 kg N/ha/yr. Boron is applied most years as a foliar spray but was missed in 2011. Additional nitrogen is added to the soil from sheep grazed in the orchard between April and December. Soil samples taken in 2011 showed low levels of all nutrients except phosphorous but levels in the leaves were adequate (though at the lower end of the required range) except for magnesium and boron. Leaf N levels ranged from 2.5 to 2.9% (from 3 different varieties sampled). At these levels, no extra N is required.

Crop levels in 2011 were assessed as "moderate", following a high crop year in 2010. Yields from the 8 Whiteheart trees averaged 2.2 kg/tree or 1408 kg/ha (measured from area of canopy cover). Four Barcelona trees gave an average of 7.18 kg/tree, for a crop of 2296 kg/ha.

Annual shoot growth ranges from 15 to over 60 cm depending on the crop load of the branch and vigour of the variety. The vegetative growth in this orchard is excessive and fertilizer applications should aim to reduce nitrogen levels while increasing levels of boron and magnesium.

## Discussion

Annual extension growth of 15 to 40 cm is required to achieve good yields from hazels (Bergoughoux et al, 1978).Trees in both Taupo orchards are achieving these growth rates.
Both Taupo orchards lack acceptable numbers of late pollinisers. This could be limiting production on the late flowering varieties such as Waihi, Plowright, and Whiteheart. Significant levels of bacterial blight were found only on those trees of the Waihi variety exposed to southerly winds in the Turangi block.

Observations from the two Taupo orchards indicate that hazels grow well in the Taupo climate and that yields similar to average yields recorded in the main hazelnut growing areas should be achievable from well managed orchards.

**Nut quality Assessments**

The 2010/11 season was characterized by humid weather conditions over the period leading up to harvest. Results are detailed in Table 1.The table also contains nut quality data from Lincoln University[1] and the 2008 harvest at Wairata[2] to provide an indication of the nut quality that can be expected from areas with drier climates or from seasons with less humid pre-harvest and harvest weather. These figures are typical of the percentage of good nuts that can be expected from harvests in the Taupo area during drier summers than experienced during 2011.

The incidence of mouldy kernels on Tonda di Giffoni was very high (29-32%) and all varieties exhibited some mouldy kernels and black tips. The percentage of good nuts declined (from 59% to 49% at Turangi, 56 to 41% at Wairata) for Tonda di Giffoni nuts harvested off the ground at the end of harvest when compared with those harvested off the trees in early February. This was due to an increased number of kernels with mould and black tips. Mould and black tips in Barcelona nuts also increased over the same period. Levels of mould were higher at Wairata for all varieties.

Nuts off the Tonda Romana, Plowright, Waihi and Whiteheart varieties had fewer faults than Barcelona and Tonda di Giffoni. Tonda Romano had less shriveled kernels. Plowright, Waihi and Whiteheart had less mouldy kernels. These varieties have no fibre on the kernels and have a low susceptibility to development of mould. The high number of mouldy kernels in the Waihi nuts at Wairata is unusual for that variety. Defective nuts for Whiteheart were also unusually high. Usually this variety has no mouldy kernels but mould was evident in the 2011 crop. An increase in the incidence of mould in South Island Whiteheart nuts harvested in recent damp seasons has also been noted in nuts processed by The Hazelnut Company (A. Mathewson, pers. comm.).

In general, kernels from the Turangi nuts were superior in visual appearance to those from the Wairata Forest Farm orchard with a paler pellicle, and less fibre cover. Nuts from Poihipi Road were intermediate between the Turangi orchard and Wairata.

Five kernels from the Turangi orchard and two from the Poihipi Road orchard showed evidence of damage caused by the Green Shield Beetle (*Nezara viridula*), indicating that this pest is present in the Taupo catchment. Green shield beetles feed on the nuts and cause the kernels to develop objectionable flavours.

**Discussion**

Defective nuts include blanks (nuts with no or very small kernels within the shell), twins (two kernels in a shell), mouldy nuts, kernels with black tips (caused by a weak shell suture), poorly filled nuts, and shriveled kernels. Causes of defects and varietal differences are summarized by Mehlenbacher (1991). The percentage of defective nuts is influenced by both genetics (causing varietal variations in susceptibility to defects) and environmental conditions that promote expression of those defects. There are important varietal differences in the production of blanks and twins, and in susceptibility to mould. Barcelona has high levels of blanks and twins while Tonda di Giffoni often has a high percentage of mouldy kernels. Poorly filled nuts and shriveled nuts are most serious problems in cultivars with large nuts.

---

1. 2011 Lincoln samples tested by the author. 1994 Lincoln data obtained from Murdoch et al, 1995. Data for 2009 Lincoln samples carried out as part of Sustainable Farming Fund project L08-088 (Redpath, 2011).
2. Data for 2008 Wairata samples carried out as part of Sustainable Farming Fund project L08-088 (Redpath, 2011)

Any environmental factor that stresses the trees during the kernel filling period (January – February) increases the number of empty, poorly filled and shriveled nuts. These factors include drought, intense heat, lack of light in the canopy, poor tree nutrition, and heavy crops (Olsen, 2002). Cool temperatures during fertilization have been suggested as one possible cause of blanks (P. Grau, pers. comm., Nov. 2011).

Table 1. Nut quality assessments for samples from the 2011 harvest at Wairata, Turangi and Poihipi Road plus additional data from the Lincoln University orchard and 2008 harvest at Wairata.

| Variety | Site | Date | Kernel (%) | Good Nuts (%) | Faults (%) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Blk | Dbl | Shr. | Bk tp | Mld | Insect dam. [4] |
| Barcelona | Wai | 9 Feb | 40.4 | 70 | 6 | 1 | 8 | 3 | 12 | 1 |
| | Tur | 8 Feb | 40.3 | 71 | 4 | 2 | 7 | 8 | 8 | 2 |
| | Wai | 1 Mar | 40.7 | 59 | 12 | 4 | 4 | 3 | 17 | |
| | Tur | 28 Feb | 42.2 | 62 | 5 | 7 | 1 | 17 | 8 | |
| | Poi [1] | 28 Feb | 41.2 | 68 | 12 | 4 | 4 | 4 | 8 | |
| | Linc | 4 Mar | 41.6 | 82 | 6 | 5 | 2 | 3 | 2 | |
| | Linc | 1994 | 36.6 | 83 | 7 | 2 | 6 | | 2 | |
| | Wai | 2008 | 40.5 | 84 | | | 8 | | | |
| | Linc | 2009 | 39.0 | 80 | 4 | | | 12 | 4 | |
| Tonda di Giffoni | Wai | 9 Feb | 42.9 | 68 | 1 | | 4 | 13 | 14 | 12 |
| | Tur | 8 Feb | 43.2 | 59 | 9 | | 1 | 14 | 17 | |
| | Wai | 1 Mar | 43.7 | 51 | 2 | | | 15 | 32 | 10 |
| | Tur | 28 Feb | 41.1 | 49 | 6 | | 2 | 14 | 29 | |
| | Linc | 4 Mar | 43.8 | 69 | 2 | 2 | 2 | 18 | 5 | |
| | Linc | 1994 | 38.8 | 68 | 12 | 2 | 6 | | 12 | |
| | Wai | 2008 | 44.5 | 66 | 7 | | | | 27 | |
| Tonda Romana | Wai | 1 Mar | 45.8 | 75 | 11 | | 1 | 5 | 8 | 11 |
| | Tur | 28 Feb | 44.7 | 84 | 9 | 1 | 1 | 2 | 3 | |
| | Linc | 4 Mar | 47.1 | 82 | 7 | 3 | | 3 | 5 | |
| | Wai | 2008 | 45.0 | 84 | 8 | | | 4 | 4 | |
| Plowright | Wai | 10 Mar | 41.5 | 81 | 9 | | 2 | 7 | 1 | 1 |
| | Tur [1] | 9 Mar | 43.3 | 89 | | 2 | 7 | 2 | | |
| | Poi [1] | 9 Mar | 40.0 | 96 | 4 | | | | | |
| | Wai | 2008 | 39.0 | 96 | 4 | | | | | |
| Whiteheart | Wai | 10 Mar | 51.7 | 84 | 1 | | 7 | 1 | 6 | |
| | Poi [1] | 9 Mar | 52.6 | 96 | | | | 4 | | 2 |
| | Linc | 4 Mar | 51.4 | 98 | 1 | | 1 | | | |
| | Linc | 1994 | 47.6 | 93 | 4 | 1 | 1 | | 1 | |
| Waihi | Wai | 10 Mar | 49.6 | 86 | 2 | | | | 12 | |
| | Tur | 9 Mar | 49.7 | 86 | 1 | | 10 | 3 | | 3 |
| | Wai | 2008 | 47.4 | 84 | | | 8 | | 8 | |

1. Samples of less than 50 nuts
2. Sites: Wai = Wairata, Tur = Turangi, Poi = Poihipi Road, Linc = Lincoln University hazel orchard
3. Faults: Blk = blank nuts, Dbl = double kernels, Shr = shriveled kernels, Bk tp = black tips, Mld = mouldy kernels.
4. Insect damaged kernels are not counted as faults for calculating the percentage of good kernels as they are not dependent on genetic or climatic influences.

Dry summer weather minimizes the development of mould. Mould was not a significant problem, even with Tonda di Giffoni nuts, in any of the Australian variety trials but blanks and shriveled nuts were a significant problem during some seasons with hot, dry summers, especially on sites with limited water (Baldwin, 2010).

Blank nuts are usually eliminated during the harvesting and/or cleaning process. Those that do make it through to the crackers do not cause any problems but shriveled kernels and kernels with black tips and mould have to be sorted out. High levels of faulty kernels slow down the sorting lines. At high levels (over 15% faulty kernels) some processors in Oregon refuse to handle the crop (pers. comm. B. Mitchell (Willamette Filbert Growers Inc.), 2008).

One variety, Barcelona, was common to all three sites sampled for this study. Barcelona is a useful indicator variety as it has a tendency to have increased fibre on the kernel in damper climates but does not have significant problems with mould in most locations. It is included in most major overseas hazelnut trials. The percent of good kernels for this variety (59-68%) in all three orchards for the 2011 harvest was low by international standards. Mehlenbacher (1990) gives a figure of 69% good kernels for Barcelona although lower figures (64%) are cited in some later trials (e.g. Mehlenbacher, 2009).The values for nuts from Lincoln (82% good kernels) and the 2008 harvest at Wairata (84 % good kernels) indicate the nut quality that can be attained in drier seasons.

The percentage of good nuts in Oregon crops, as assessed for all varieties by the USDA National Agricultural Statistics Service Oregon has ranged from 78% to 89% over the years 1991 to 2011 (USDA NASS, 2011). The majority of the trees planted in Oregon are the Barcelona variety (USDA NASS, 2008). Hazelnut orchards in the Lake Taupo catchment should be able to achieve comparable results in normal seasons. Attention needs to be given to selecting varieties with low susceptibility to mould on the western side of the catchment to minimize nut losses in wet summers.

## Comparing the climatic characteristics of the Lake Taupo catchment with climatic requirements for hazelnut production

Commercial hazelnuts require a mild temperate climate, where average annual temperatures range from 12°C to 16°C, with maximum temperatures of 35 to 36°C and minimum temperatures of -8 to -10°C (Fideghelli and De Salvador 2009). Severe out-of-season frosts can damage developing nut clusters. Ideal annual rainfall is 800 to 1000 mm, with rain evenly spread throughout the growing season. Warm dry weather over the harvest period (February and March in most areas of New Zealand) is advantageous. Hazelnut trees have soft leaves and do not tolerate extreme heat, wind and moisture stress. In New Zealand conditions, good shelter is essential.

Chilling requirements vary depending on the variety and the type of bud (male catkins: 100-1200 hrs, female flowers: 500-1200 hrs, vegetative buds: 600-1200 hrs).

Climate data for Wairakei, Turangi and Wairata are compared in Table 2. Rainfall is adequate and well distributed through the growing season at all sites. Mean values for summer rainfall are very similar for Wairata and Turangi. Wairakei is significantly drier over the summer months and irrigation will probably be required on free draining soils in this eastern side of Lake Taupo. It also has more frosts than the other two sites. Wairata is about 2°C warmer than the Taupo sites but the number of screen frost days and winter mean minimum temperatures are similar for Wairata and Turangi.

Extreme maximum temperatures range from 31.6°C (Turangi) to 33.4°C (Wairata), recorded extreme minimum temperatures for all sites are -6.7°C to -7°C. These extremes are within acceptable values for growing hazelnuts.

Out of season frosts in November and December have caused hazelnut crop losses in parts of New Zealand over the past 3 years. Temperatures recorded in orchards affected by frost damage in the South Island suggest that air temperatures of -2 to -3°C are sufficient to cause damage to nut clusters (A. Mathewson, pers. comm. 2008). While only one mummified cluster was found in the Taupo orchards, it was evidence that frost damage has occurred during 2009 or 2010. Data on frosts for the Turangi2 Ews (Station C85977) was examined to estimate the temperature of possible damaging frosts and the frequency of out-of-season frost events over the critical November-December period. Over the seven years 2003 to 2010, 9 screen frosts were recorded in Turangi in November and 1 screen frost in December. November screen frosts with minimums of less than -1°C have occurred during each of the last 3 years (2008-10) with temperatures ranging from -1.7 to -2.1°C. The yield effect of frost damage has not been determined but it would be prudent to avoid areas known to be prone to severe frosts for commercial hazelnut growing.

**Table 2: Rainfall and temperature comparisons - Wairata/Waimana*, Wairakei, and Turangi. Mean 30 year values (1070 - 2000)**

| **Rainfall** | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Annual |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Wairata | 129 | 105 | 155 | 156 | 162 | 193 | 188 | 193 | 185 | 192 | 167 | 155 | 1979 |
| Wairakei | 80 | 78 | 97 | 85 | 98 | 107 | 116 | 112 | 102 | 101 | 84 | 126 | 1186 |
| Turangi | 118 | 102 | 126 | 117 | 147 | 146 | 165 | 153 | 144 | 144 | 141 | 127 | 1630 |
| **Mean rain days** | | | | | | | | | | | | | |
| Wairata | 13 | 10 | 12 | 12 | 13 | 15 | 16 | 16 | 16 | 16 | 15 | 14 | 175 |
| Wairakei | 10 | 8 | 10 | 10 | 12 | 14 | 14 | 16 | 16 | 14 | 12 | 13 | 148 |
| Turangi | 11 | 9 | 11 | 12 | 14 | 15 | 16 | 17 | 17 | 17 | 14 | 14 | 168 |
| **Mean air temperature** | | | | | | | | | | | | | |
| Waimana | 19 | 19 | 17 | 14 | 11 | 9 | 8 | 9 | 11 | 13 | 15 | 17 | 14 |
| Wairakei | 17 | 17 | 15 | 12 | 9 | 7 | 7 | 7 | 9 | 11 | 14 | 16 | 12 |
| Turangi | 17 | 17 | 15 | 12 | 9 | 7 | 7 | 7 | 9 | 11 | 14 | 16 | 12 |
| **Mean daily maximum temperature** | | | | | | | | | | | | | |
| Waimana | 24 | 24 | 23 | 20 | 17 | 15 | 14 | 15 | 17 | 19 | 21 | 22 | 19 |
| Wairakei | 24 | 24 | 22 | 18 | 15 | 12 | 12 | 13 | 15 | 17 | 19 | 22 | 18 |
| Turangi | 23 | 23 | 21 | 18 | 14 | 12 | 11 | 12 | 14 | 16 | 19 | 21 | 17 |
| **Mean daily minimum temperature** | | | | | | | | | | | | | |
| Waimana | 13 | 13 | 11 | 8 | 5 | 3 | 2 | 3 | 5 | 8 | 10 | 12 | 8 |
| Wairakei | 10 | 10 | 9 | 6 | 4 | 2 | 1 | 2 | 4 | 6 | 8 | 9 | 6 |
| Turangi | 12 | 12 | 10 | 7 | 4 | 3 | 2 | 3 | 5 | 7 | 8 | 10 | 7 |
| **Days of screen frost (mean)** | | | | | | | | | | | | | |
| Waimana | 0 | 0 | 0 | 1 | 4 | 10 | 11 | 8 | 2 | 0 | 0 | 0 | 38 |
| Wairakei | 0 | 0 | 1 | 2 | 8 | 11 | 13 | 10 | 5 | 2 | 1 | 0 | 53 |
| Turangi | 0 | 0 | 0 | 1 | 6 | 9 | 11 | 8 | 4 | 1 | 0 | 0 | 39 |
| **Sunshine hours** | | | | | | | | | | | | | |
| Turangi | 222.5 | 194.1 | 173.4 | 163.1 | 147.1 | 101.8 | 116.1 | 135.1 | 136.2 | 171.3 | 186.1 | 191.6 | 1938 |
| Waimana | 186.5 | 178.3 | 186.4 | 144.7 | 140.4 | 114.4 | 107.8 | 153.3 | 144.9 | 174.6 | 162.7 | 184.4 | 1878 |

* Historic temperature data for Wairata is not available. Data from the Waimana station (Agent No 1883) has been used. Waimana is the closest weather station to Wairata with similar climatic conditions.

**Discussion**
Climatic data from three important overseas hazelnut growing areas are compared with data from Wairata and Turangi in Table 3. The most significant difference between the New Zealand and overseas sites is the greater rainfall and rain days experienced by the New Zealand sites, especially during the harvest month (March).

**Table 3: Comparison of key climate data from Turangi and Wairata with three major overseas hazelnut growing regions**

| | | Location | | | | |
|---|---|---|---|---|---|---|
| | | Ordu Northern Turkey | Nola Campania Italy | Corvallis Oregon USA | Turangi Taupo NZ | Wairata* BOP NZ |
| Latitude | | 41°N | 41°N | 45°N | 39°S | 38°S |
| Climatic data | | | | | | |
| Mean annual rainfall (mm) | | 990 | 1010 | 1050 | 1630 | 1979 |
| Hottest month | Mean max. (°C) | 25 | 30 | 27 | 23 | 24 |
| | Mean rain (mm) | 68 | 29 | 14 | 102 | 105 |
| | Rain days | 5 | 4 | 3 | 9 | 10 |
| Coldest month | mean min. (°C) | 3 | 5 | 1 | 2 | 2 |
| | Mean rain (mm) | 95 | 111 | 173 | 165 | 188 |
| | Rain days | 10 | 11 | 19 | 16 | 16 |
| Harvest month | Mean rain (mm) | 72 | 79 | 38 | 126 | 155 |
| | Rain days | 6 | 5 | 6 | 11 | 12 |
| International data from Baldwin, 1998? NZ data downloaded from Cliflo. | | | | | | |
| * Temperature data for the Wairata taken from the Waimana weather station, the closest weather station to Wairata with temperature data. | | | | | | |

There are obvious benefits from having warm dry weather over the harvest - moisture content of the nuts is low, husks dry quickly allowing nuts to fall free, and ground conditions favour easy machinery operations and clean nuts. Drying costs are reduced. The main hazelnut growing areas in the South Island of New Zealand have experienced damp weather conditions over the last two harvest seasons and three problems associated with harvesting in damp conditions have been identified;

1. Buildup of silt and clay in tubes and drums of vacuum harvesters has occurred on silt and clay based soils, slowing down harvest;
2. Nuts retained in the husks, necessitating extra drying and processing with potential loss of nut quality;
3. Increased incidence of black tips and mould on kernels.

The retention of nuts in the husks has been a significant problem with Whiteheart, the main variety grown in New Zealand. Whiteheart has a clasping husk that often fails to split in damp seasons, causing some harvesters to sort the clusters of nuts out with stones and heavy debris. The unopened husks then need to be further dried before being put back through the harvesters or put through dehusking equipment before drying. Free husking varieties such as Barcelona tend to fall out of the husks during the harvesting operation even in damp seasons. The selection of varieties for areas with damp summers needs to focus on free husking genotypes with low frequency of mouldy kernels.

Georgia is a major overseas hazelnut growing nation with hazelnut production in the humid western regions with well distributed rainfall through the summer months. Fig 1 compares the climate of Turangi with that of the Zugdidi region in western Georgia. AgriGeorgia, a subsidiary of

Ferrero, the Italian confectionary company, has planted about 2500 hectares of hazels in this area, made up of both Georgian and Italian varieties, including Tonda Romana and Tonda di Giffoni (AgriGeorgia, 2010). Traditionally hazelnuts in Georgia have been hand picked off the trees but the Ferrero orchards will be managed for mechanized harvest. Compared with Zugdidi, the Taupo region has lower rainfall over the pre-harvest and harvest period.

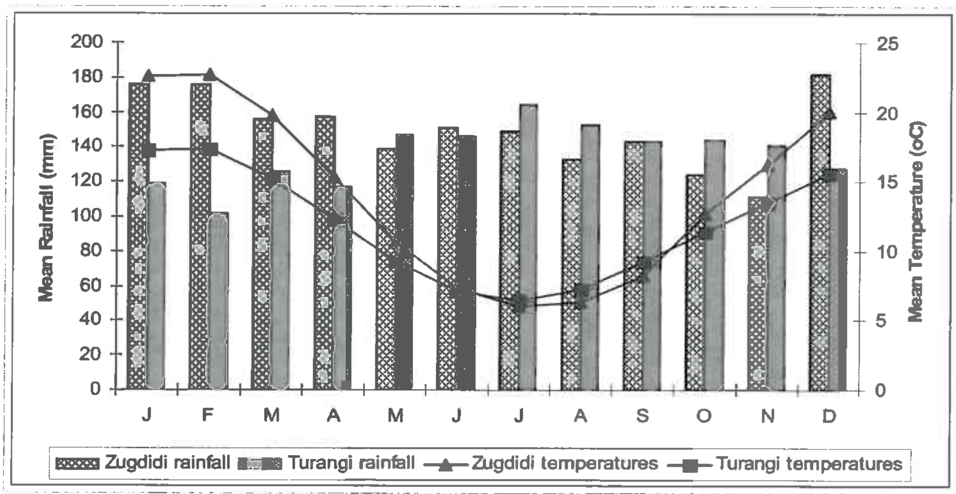



Fig 1: Comparison of climate data from Turangi and Zugdidi, Georgia (site of large hazelnut plantings by Ferrero) Georgian data offset by six months to correspond with southern hemisphere seasons.
(NZ data from http://cliflo.niwa.co.nz/ Georgian data from http://www.climateprojects.info/chameleon/outbox//9b5b4ccf1878b51c58d2d10216e8cf28/PDD_HAP_CFS.pdf.)

The climate of most of the Lake Taupo catchment is suitable for hazelnut production. Frost flats or areas subject to extreme frosts should be avoided. Rainfall on the western side may be adequate for growing hazels without irrigation. No measurable effect on hazelnut yields or nut quality has been noted in the Wairata Forest Farm orchard in years when summer drought has severely affected pasture growth. A well distributed rainfall of 800 mm/year is required for growing hazelnuts without irrigation (Fideghelli and De Salvador 2009). Most hazels in Oregon are grown without irrigation in a climate with about 1000mm of rainfall with most falling in winter. Most Oregon orchards are on deep alluvial loam soils with good water holding capacity. Most hazelnut roots are in the top 60 cm of soil but they will develop active root systems to depths of 1.8 to 3 metres in suitable well aerated soils (Olsen, 2002) and can draw water from below the depth of most grass roots.

Some of the deep sandy soils in parts of the Taupo region have low available water capacity, as detailed in Brown and Haigh (2004). Those soils with available water capacities of 40-70 mm, such as Taupo sands, will possibly require irrigation over the period of nut fill (December to early February). The need for irrigation on these soils may need to be investigated. On soils with higher available water capacity, the cost of irrigation should be avoided if possible.

In most years the summer weather at Wairata enables adequate drying for a trouble free harvest and adequate drying during harvest should not be a problem in the Lake Taupo catchment. Nut quality assessments from the single 2011 harvest cannot be taken as proof that varieties such as Tonda di Giffoni cannot be grown successfully around Lake Taupo but any varieties that are susceptible to blight may be better suited to the drier eastern side of the catchment.

## 2: Nitrogen use in hazelnut orchards

Nitrogen plays an essential role in tree growth, nut yields and nut quality. Studies in hazelnut orchards have shown that applying nitrogen increased shoot growth, individual nut size, total yield, reduced the number of blanks (empty nuts) and improved kernel to shell ratio and taste panel scores (Chaplin and Dixon, 1979, De Salvador et al, 2009). Excessive N applications (over 1.8 kg N per tree) were found to lead to reduced shoot growth and yields in Oregon (Chaplin and Dixon, 1979). If leaf levels are optimal, recommendations for N applications in mature orchards for the Oregon industry are for 0.68 to 0.91 kg/tree (183 – 245 kg/ha). Tous et al (2005) found negative effects on yield at lower application rates (150-200kg/ha) in orchards on sandy loam soils in Spain. He found no significant differences in yield or nut quality between 50kg/ha and 100 kg/ha treatments and recommended a rate of 50 kg N/ha if leaf N levels are near the optimum levels (2.2 – 2.5% DM). Additions of between 40 and 70 kg N/ha/yr are planned for orchards planted in the high rainfall areas of Georgia by Ferrero (TÜV SÜD Industrie Service GmbH Carbon Management Service, 2011)

Young trees are especially sensitive to excessive nitrogen applications. Braun et al (2011) found that deaths of 1 year trees increased with increasing levels of nitrogen applied at planting. Nitrogen applications are not recommended during the first two years after planting.

Most of the nitrogen requirement for the spring growth of hazel trees is provided by nitrogen reserves stored in the buds, shoots and roots. Olsen et al (2001) found that hazel trees in Oregon take up little N from the soil until May – June (November – December in New Zealand). Application of solid fertilizer to the ground in spring resulted in a 28% recovery of the N applied. Treatments using foliar applied urea showed that a large portion of the nitrogen applied was translocated to the kernels when applied during the period of kernel development (December in New Zealand).

Nitrogen levels in leaves and shoots are at their maximum in the spring and decline through summer as the nuts develop (Bignami et al, 2005).

Hazelnuts kernels consist of 10% to 20% protein (Mehlenbacher, 1991) and are a strong N sink that is removed with the crop. Baldwin (2010) found that the N levels in hazelnut kernels in varieties in the trial at Kettering in Tasmania ranged from 5.9% for Ennis to 7.47% for Lewis. Estimated removal of N with the crop (using average percent kernel values from the same trials) would range from 24.19 to 35.86 kg of N per tonne of nuts.

Nitrogen is also lost from the trees during leaf fall, dropping of spent catkins in winter, husks at harvest, and removal of suckers and prunings. Bignami et al (2005) estimated that the annual removal of N from trees in leaves, nuts, husks, catkins, suckers and prunings amounted to about 74 kg/ha in a mature high producing Tonda Romana hazelnut orchard in central Italy. This orchard was fertilized with 90 kg/ha N annually. Nearly 35kg/ha of nitrogen accumulated in the nuts and was removed from the orchard at harvest. Lower figures for annual N removal from trees (43-62 kg N/ha for total biomass removal, 6.5 kg N/ha in nuts) are documented by Roversi and Ughini (2006) in less productive Tonda Gentile delle Langhe orchards in northern Italy.

No studies into N leaching from hazelnut orchards have been found. General influences on N leaching from orchards are discussed in Menneer et al, 2003. Orchards offer far greater opportunities than livestock farming to control possible loss of nitrogen from the soil, with fertilizer only required during periods of active growth in spring when uptake is maximized.

**Implications of the EW regulations on nitrogen use for hazel orchards in the Lake Taupo catchment**

Under rule 3.10.5.1 of the regulations governing nitrogen use in the Taupo catchment (Waikato Regional Council, 2011), hazel orchards would be classed as a "Low Nitrogen Leaching Farm Activity", provided total annual fertilizer nitrogen requirements are no more than 75 kg/ha. This would make hazelnut orchards permitted activities not requiring land use consents.

Yields achieved from the Wairata Forest Farm Variety Collection over the last 30 years, overseas research (e.g. Tous et al, 2005) and observations from the hazel orchard at Turangi, suggest that commercial yields could be achieved in the Taupo catchment with applications of up to 75 kg/ha of nitrogen. Research is required to determine whether high yields can be maintained on the free draining volcanic ash soils at these application rates.

For livestock farms with an existing Nitrogen Discharge Allowance and nitrogen leaching rates typical of commercial livestock farms, converting land to hazelnut orchards will lower the amount of nitrogen leached. Assuming "typical" rates of nitrate leaching of 49 kg N/ha/year for dairy farms and 14 kg N/ha/year for sheep and beef farms (Ledgard et al, 2001) and leaching of 8 kg N/ha/year for hazelnut orchards, each hectare converted to hazelnut orchards would create an excess allowance of 41 and 6 kg N/ha/year for dairy farms and sheep and beef farms respectively. Landowners could sell the excess nitrogen allowance created or use it to increase stocking rates on other parts of the farm.

This project has treated hazelnut growing as a "farming" land use when considering it's fulfillment of nitrogen leaching requirements. The final canopy cover of a productive hazel orchard could range from 70 to 100% canopy cover and the characteristics of nutrient flows may move towards those found in forests, especially if all prunings are mulched back into the soils to increase the C/N ratio in the soils and increase the potential for nitrogen immobilization. It is noted that rule 3.10.5.2. (Permitted Rule Activity – Nitrogen Leaching Non-Farm Activities) allows up to 240 kg/ha of nitrogen per application to be broadcast on production forests provided it is broadcast between 1st September and 31st May. Given that any applications of nitrogen in hazel orchards would occur between October and January, there appears to be some scope for mature hazel orchards to be treated as "forests" under the Variation 5 rules, allowing applications of nitrogen greater than 75kg/ha (if required) while still achieving the aims of the land use regulations.

Rules 3.10.5.4 and 3.10.5.5 allow for the development of forestry and unimproved land if the increase in nitrogen discharges are kept under 2 kg N/ha/year above the deemed existing nitrogen leaching rates (set at 2 kg N/ha/yr for unimproved land and 3 kg N/ha/yr for plantation forestry). If landowners wish to develop land suitable for hazelnut production under these rules, research to establish the level of nitrogen leaching from hazel orchards could be considered to determine whether leaching rates can be kept within these levels.

**Discussion**

Leaf N levels in the orchards at Taupo and Wairata indicate that the N inputs into these three systems were adequate for the yields achieved. The input from animals in the Turangi and Wairata orchards are not known.

The greatest reductions in N leaching from changing land use from livestock production to hazelnut production will occur with the total exclusion of animals from the land. Growth rates of hazel trees in the Taupo catchment during the period of maximum growth in late spring should allow rapid uptake of N applied in spring fertilizer applications, with no N applications needed during the periods of greatest leaching potential over autumn and winter. Additions of N fertilizer may be further minimized if the orchard floor is maintained in a clover rich ground cover to maximize natural nitrogen fixation. Goh et al (1994) report N fixation rates of between 12 and 105 kg N/ha/year in an organic apple orchard, with the amount of N fixed dependent on the proportion of legumes in the understory. It is possible that the clover-fixed nitrogen released during mowing of the orchard floor may be able to provide much of the required nitrogen when combined with the mineralization of N added to the soil via leaves, catkins, suckers and prunings from previous seasons. Additional fertilizer nitrogen may need to be applied only during heavy crop years to minimize biennial bearing tendencies. The use of foliar applied urea would allow precisely timed applications designed to minimize losses in wet weather.

If hazelnut orchards are integrated into livestock farms it may be possible to utilize N inputs from animals to provide the N requirements for the trees. The leaf N levels in the orchards at Turangi and Wairata were high despite having no or low inputs from fertilizers. Both orchards are grazed for part of the year and it is likely that a large part of the N inputs come from urine. If hazel orchards can be used to absorb some of the excess N from livestock operations and convert it into a saleable product then there are benefits from lower N leaching from livestock (through lower total stock numbers on the property) and lower costs for the hazel orchard. Two options could be investigated:
1: Using dairy effluent or effluent from winter feed-pads. Applications would be made during September, October and November.
2: Grazing with sheep between harvest (March) and December. This period corresponds with low growth of pasture and the additional grazing area offered by the hazelnut orchard may provide opportunities to carry extra stock units over winter. Experience at Wairata is that the period of greatest pasture growth within the orchard is during the spring (September to November). After November the shading from the canopy reduces growth under the trees. Sheep are successfully grazed in some New Zealand hazel orchards at present and offer several benefits including control of the understorey vegetation and sucker control.

If orchards are grazed or applications of effluent used in the orchard, landowners must ensure that no effluent or faecal material remains at harvest. Research will be required to prove that these options do not result in elevated levels of coliform bacteria on the orchard floor at harvest before these systems can be recommended. Post-harvest washing systems would need to include systems to sterilize the nut surface using chlorine or ozone. It is possible that food regulations may eventually prohibit any grazing in nut orchards

## 3: Determining the area of land in the Lake Taupo catchment suitable for hazelnut growing

Land use capability data provided by the Waikato Regional Council showed a total of 64,405 hectares of class 3 and 4 land (listed in Table 4 and shown in Fig 2). These areas are similar to those mapped as possibly having "good" potential for hazel growing on a map available on the NIWA website (www.niwa.co.nz/our-science/climate/research-projects/all/assessment-of-crop-and-tree-species-growing-potential-using-climate,-soil-and-topograp).

**Table 4 Area of land suitable for commercial hazelnut production in the Lake Taupo catchment**

| LUC units | Soils | Predominant Land cover | Area (ha) | Notes |
|---|---|---|---|---|
| Land suitable for commercial hazelnut production | | | | |
| 3s2 | Taupo deep sand | pasture | 621 | Probably requires irrigation |
| 3s6 | Turangi sandy loam | pasture | 1994 | |
| 3s6 | Waipahihi sand | pasture | 183 | Possibly requires irrigation |
| Land with moderate limitations to commercial hazelnut production | | | | |
| 3e7 | Taupo sand/deep sand | pasture | 1264 | Probably requires irrigation, contour planting |
| 3e12 | Waipahihi sand | pasture | 782 | Possibly requires irrigation, contour planting |
| Land suitable for commercial hazelnut production with potential for urban or peri-urban development | | | | |
| 3s, 3e, 3w | Various | pasture | 2066 | |
| Land suitable for hazelnut production in commercial forests | | | | |
| 3s6 | Waipahihi sand | forest | 518 | |
| 3s6 | Turangi sandy loam | forest | 1276 | |

While hazels will grow on all this land, assessing the potential for profitably developing hazel orchards requires that consideration be given to any need for environmental modification (land contouring, drainage, the need for irrigation), land values, and the economic cost of changing land use (especially for forested land). Soils developed on pumice are very susceptible to erosion and this must be a consideration when assessing the suitability for commercial orchard development. Other considerations are the potential for sub-division into urban or peri-urban developments and additional costs associated with the conversion of forested land to orchards.

**Land with potential for peri-urban and urban development**

The areas classed as "peri-urban" are close to the lake edge or urban areas and are therefore likely to have land values that reflect their potential for subdivision rather than reflecting the productive potential of the land class. Hazelnuts are a potential use for this land but the experience of the development of the NZ nut industries suggests that the economic viability of small orchards is dependent on infrastructure supported by investment either by larger orchards or co-operative ventures by groups of smaller growers to achieve the same critical investment.

Hazelnuts have been promoted as a crop that suits the requirements of "lifestyle" property owners, with most inputs (development costs, management costs, and labour requirements) lower than other crops. As a result, most New Zealand hazelnut orchards are located on small "lifestyle" blocks. Experience within the industry is that orchard management is extremely variable with wide variations in yields and nut quality. Properties frequently change ownership, often with a change of land use or quality of orchard management.

These characteristics create difficulties planning for and establishing profitable systems to process and market the crop. To achieve the economies of scale required to successfully develop a new industry within the region, the main initial plantings should be large commercial orchards that can rapidly generate the yields and cash flow that allow investment in the required processing facilities. The infrastructure established to service these large plantings (e.g. harvesters, washing and drying facilities) is then available to allow smaller orchards to economically harvest and process their crop.

**Conversion of forested land**

The economics of developing hazelnut orchards after harvesting commercial forests are dependent on the age of the forests (pre-1990 or post-1990) and the future of the Emissions Trading Scheme, especially negotiations for a change of rules to allow offsetting. Under most international definitions hazelnuts could be classed as a forest tree (with the potential to grow more than five metres in height) and a mature hazel orchard could be defined as a forest with 70% to 100% canopy coverage. However, fruit and nut orchards are specifically excluded from carbon accounting under the NZ Emissions Trading Scheme ("Forest species are trees capable of reaching five metres in height at maturity in the place they are growing, *excluding tree species grown primarily for the production of fruit and nut crops".* MAF, 2011, p10). Under these rules, the carbon sequestered by the hazel orchard cannot be used to offset the deforestation liabilities because a commercial hazelnut orchard, grown for the purpose of harvesting a crop of nuts, will not be classed as a 'forest'. Any conversion of pre-1990 forests, or post- 1990 forests that have sold carbon, will have to purchase carbon credits and converting the land is unlikely to be economic unless offsetting of the commitments is allowed in future.

The conversion from forest to alternative land uses also faces restrictions on increased nitrogen leaching under the Section 5 rules.

Land formerly in Pinus radiata forests are being converted to hazelnut orchards in Chile (P. Grau, pers. comm., 2011).

**Suitability of the various land classes for hazelnut production**

***Class 3s***

All Class 3s land would be suitable for commercial hazelnut growing, being flat land with moderate soil based limitations. The total area of class 3s land in the Lake Taupo catchment is 5750 hectares. The largest areas occur just south of Turangi and on the western edge of Lake Taupo. Soils are Taupo deep sand, Waipahihi sand and Turangi sandy loam.

Small areas of 3s land between Kinloch and Taupo, and adjacent to Turangi and Kuratau, were considered to have urban or peri-urban potential.

There are 2600 hectares of pasture based 3s land suitable for commercial hazelnut orchards.

***Class 3e***

Most class 3e units lie adjacent to the 3s units and consist of similar soil types to adjacent 3s land on land with gentle slopes. The 2000 hectares (approx.) of class 3e land that could be used for commercial hazelnut production excludes a number of small isolated blocks and land adjacent to urban areas. Consideration should be given to contour planting and the maintenance of grassed inter-row areas to prevent downslope soil movement.

There are three small areas of 3e land at Tihoi, Rumata Road and west of the Kuratau Junction, locations isolated from the other main areas of suitable soils. The area of 3e land available at each individual location is large enough to be developed into an economic hazelnut orchard, but these units are all in western areas with higher rainfall and careful consideration must be given to control of erosion. Development of these areas would also need to be balanced against the requirements of these farms for land for hay and/or finishing livestock.

***Class 4 land areas***

It is considered that most class 4 land has limitations that could significantly lower the economic returns from the establishment of hazel orchards.

Further studies are required to establish whether class 4e land can be economically developed for commercial hazelnut production using conventional orchard management techniques without increasing risks of accelerated soil erosion. Conventional orchard management allows a dense canopy to develop with a bare or sparsely vegetated orchard floor. In these conditions it is likely that soil erosion could be a problem. Erosion is a consideration in recent plantings in Chile (P. Grau, pers. comm., Nov 2011) where maintenance of grass strips between rows is promoted for vulnerable sites. It may be possible to minimize the erosion risk by planting rows along the contour and adopting a wider final spacing (e.g. 8 m x 8 m, depending on the vigour of the variety) to allow the maintenance of a dense grass sward on the orchard floor. Regular pruning would be required to maintain adequate light to the orchard floor.

Some units mapped as 4e do contain areas of 3s and 3e due to the scale of mapping. If these areas of Class 3 land were developed into hazel orchards, it may also be economical to develop some areas of the adjacent class 4e land.

Class 4s4 land (2447 ha.) consists of a range of soils located adjacent to Lake Taupo and Lake Rotoaira. Many of these soils are suitable for growing hazelnuts. For example the Turangi orchard in Grace Road is mapped in a 4s4 unit on Huka sand soils. However, the location of these units close to the lakes gives this land potential for development for urban or peri-urban use or for conservation. There are also possible climatic limitations to growing hazels commercially on class 4s4 land around Lake Rotoaira (776 ha.) due to the greater risk of severe late frosts.

Class 4s5 land consists of free draining Kaiangaroa and Otamatea soils east of the lake. These soils are considered to be marginal for commercial hazelnut production, requiring careful fertilizer management and irrigation. Most of this land class is in commercial forests.

The 1047 hectares of Class 4w1 land are all adjacent to the lake and would require drainage for successfully growing hazels. All this land has conservation or subdivision values that limit the potential for economically developing commercial hazelnut orchards.

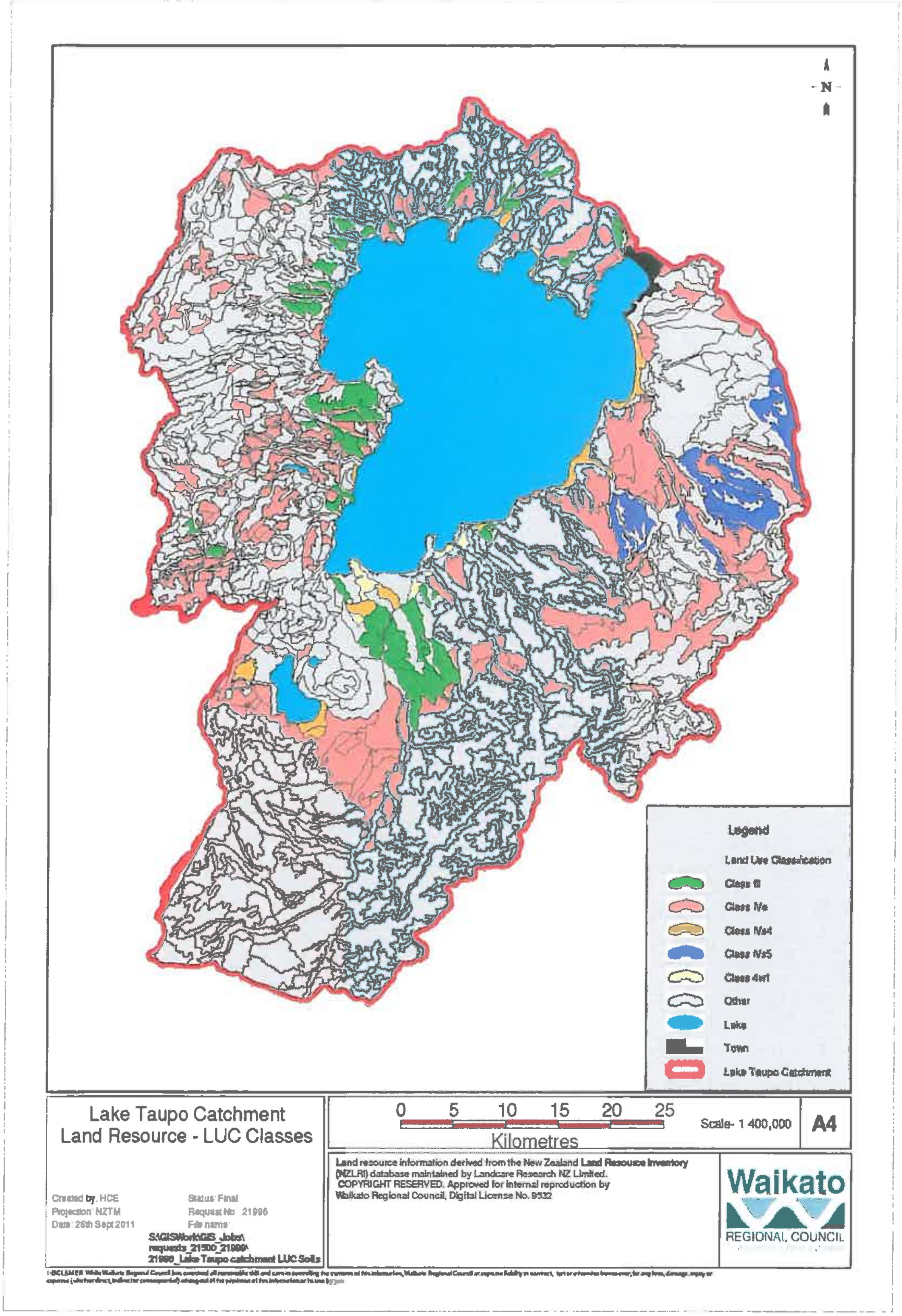



Fig 2. Land classes assessed for hazelnut growing in the Lake Taupo catchment. Class 3 land (green) is physically suitable for commercial hazelnut production

## 4: Estimated costs and returns of establishing and producing hazelnuts in the Lake Taupo catchment.

The estimated costs and returns of establishing and producing hazelnuts in the Lake Taupo area are given in Appendix 1, along with the assumptions used to calculate the cash flow. This budget assumes that irrigation is not needed and high yielding varieties such as Barcelona or Tonda di Giffoni are planted. Estimates for gross margins for mature orchards are given in Table 5.

**Table 5. Estimate of the gross margin per hectare for an unirrigated mature hazelnut orchard in the Lake Taupo catchment**

| | | |
|---|---|---|
| **Income (per hectare)** | | |
| 2500kg @ $3/kg | $7500 | |
| **Gross income** | | $7500 |
| | | |
| **Expenditure (per hectare)** | | |
| Fertilizer (including lime) | $185 | |
| Mowing | $680 | |
| Weed control | $51 | |
| Sucker control | $114 | |
| Pruning | $653 | |
| Pest control | $28 | |
| Pre-harvest grass spray | $50 | |
| Harvest costs | $300 | |
| Washing and drying | $250 | |
| Freight | $125 | |
| Shelter trimming | $250 | |
| **Total direct costs** | | $2686 |
| **Gross margin per hectare** | | **$4814** |

Baldwin (2010) estimated the gross margin for hazelnut growing in Australia at $A4400/ha. The USDA Foreign Agricultural Service give a figure of 2500 – 3000 Euros/ha ($NZ4322 – 5187, converted 25/10/11) for Italian orchards (USDA FAS 2011a). Calculations from figures in Julian et al (2009) give gross margins from Oregon orchards of $US3325 ($NZ4422) at crop prices of 70 cents/lb. The calculated returns for Taupo orchards are comparable with these figures.

The gross margin for growing hazelnuts is higher than the gross margins for most livestock operations. The gross margin for Waikato/Bay of Plenty dairy farms, calculated from the 2010/11 figures given in the MAF 2011 Pastoral Monitoring models, is $4011/ha. Using the concept of comparing farm returns in terms of dollars per kilogram of nitrogen leached, the hazelnut gross margins presented here, assuming leaching of $8kg N/ha/year from a hazel orchard, return a figure of $602/kg N, well above comparable returns for any of the livestock options investigated by Thorrold (2006).

Costs associated with orchard floor maintenance are higher in this budget than would be normal for overseas hazelnut orchards. This reflecting the costs associated with maintaining a dense grass sward in the inter-row area to prevent soil erosion. This increases mowing costs and adds the possible cost of suppressing the grass sward over the harvest period. It also assumes constant grass growth through the summer so mowing costs would be lower during dry summers. These mowing costs could be reduced through selection of suitable slow growing turf grasses or harvesting of the grass for feed (with the cost of harvest offset by the value of the grass harvested). Oregon growers grow a range of crops (including wheat, clover (for seed) and vegetable crops) between the rows of trees in newly planted orchards for the first 3 years up to the first harvest to maintain cash flow during this period.

Livestock farms usually have a range of equipment that can be used for land preparation and orchard floor management. The main capital equipment costs are a tractor mounted harvester ($30,000 to $70,000) and, perhaps, a flail mower ($13,000) for preparing the orchard floor prior to harvest. Alternatively, these services can be provided by contractors.

The most significant problem for Lake Taupo landowners wanting to establish hazelnut orchards is the lack of hazelnut processing facilities in the North Island. The only large hazelnut cracking plant is in Canterbury. Freight costs for the small shipments of nuts sent down from the North Island are over $0.80/kg. The cost of washing and drying the harvest is also difficult to accurately price. Oregon costs have been used in this analysis, assuming that large scale efficient systems will be used. P. Grau (pers. comm., 2011) quoted costs of 19c/kg in Chile. Costs of $1/kg for washing and drying were used in calculating the gross margin for hazelnut growing in Tasmania (DPIPWE, 2011). Using these higher costs would lower the gross margin in this analysis to around $2500/ha. It may be possible to establish cost effective washing and drying facilities close to Taupo using waste geothermal heat.

Key factors influencing the profitability of hazelnut orchards are the price received for the crop and the yields achieved. Table 6 provides a sensitivity table comparing gross margins at various yields and returns, using the costs given in the gross margin analysis.

**Table 6. Sensitivity analysis of gross margin ($/ha) to crop price and yield**

| | Yield of nuts in-shell (tonnes/ha) | | | |
|---|---|---|---|---|
| Crop price ($/kg) | 1.5 | 2.0 | 2.5 | 3.0 |
| $2.50 | $1305 | $2480 | $3655 | $4830 |
| $3.00 | $2055 | $3480 | $4905 | $6330 |
| $3.50 | $3805 | $4480 | $6155 | $7830 |

The values for price received ($3/kg) and the yields (2.5 tonnes/ha) in these calculations are realistic and achievable assuming that productive varieties will be grown and average yields typical of well managed Oregon hazelnut orchards are achieved.

Minimum prices for Oregon growers for the 2011 harvest were set at $US1.10 per pound[3] ($NZ3.23/kg[4]), the highest base field price ever, with the Hazelnut Growers of Oregon cooperative setting the initial price at $1.20 per pound. 2011 prices in Chile were $US2.80/kg ($NZ3.72) for Barcelona nuts and $US3.40 ($NZ4.52) for Tonda di Giffoni nuts (P. Grau, pers. comm. 2011). Prices paid by New Zealand processors have ranged from $3.50 to $6/kg in recent years but increased supply and the impact of the NZ dollar driving down the price of imported kernels are limiting the opportunities to achieve the higher prices.

New varieties being released from the Oregon State University breeding programme, such as Jefferson, are both productive and precocious, cropping a year earlier than older varieties with a more rapid increase in yield. Using average yields for Jefferson from two trials quoted in Mehlenbacher (2009) in this analysis increases the gross margin to nearly $7000/ha. More important, the first year of profit is the year 3 rather than year 5 and the year at which all costs of planting are recovered occurs four years earlier. An optimistic budget using these new varieties and assuming a crop value of $3.50/kg delivers a gross margin of almost $8500/ha.

---

3: "*Hazelnut prices set new record.*" Press article viewed online at www.capitalpress.co./content/js-filbert-price-100711

4: $US to $NZ conversions based on $US1 = $NZ0.75

Orchards with yields comparable to those achieved in the main overseas growing regions have been observed by the author in Bay of Plenty (podzolized pumice soil), Hawke's Bay (sandy loam on gravel), Wairarapa (recent silty sand soils), Nelson (silt loam), South Canterbury (stony silt loam), Otago (clay loam) and Southland (silt loam).

While estimates from individual orchards for single years have indicated that crops of about 3 tonnes/ha may be achieved in some New Zealand orchards, there is insufficient yield data recorded from trials or orchards here to be able to accurately assess the potential yields for the hazelnut orchards in New Zealand. To provide the industry with an accurate assessment of the yields in New Zealand commercial hazelnut orchards, the Hazelnut Growers Association (HGANZ) has started a project[5] to collect yield data from growers over the 2011 – 2013 harvests.

A trial planted at the Appleby Research Orchard in Nelson was assessed for yield from 1970 to 1975. One cultivar, incorrectly labeled as Barcelona but later renamed 'Appleby', yielded an average of 10.3 kg per tree over that period (DSIR, unpublished data).[6] At the spacing used in that trial, this equated to a crop of over 4 tonnes per hectare. This is an excellent crop by international standards.

A variety trial established at Lincoln University in 1985 gave yield results similar to those recorded in Oregon (USA) up to year 6 but then yields failed to achieve the levels recorded in Oregon (Murdoch et al, 1995). Shading within the older trees was suggested as a possible cause of the lower yield efficiencies in the older trees. Observations at Wairata support that suggestion. It is possible that stress from persistent dry winds typical of the Canterbury climate may have also limited the ability of the trees in the Lincoln trial to reach their full yield potential. Increases in yield from the Wairata Forest Farm Variety Block over the first 8 years after planting were more typical of those achieved in Oregon, with over 5 kg/tree off Barcelona trees by year 9 (M. Redpath, unpublished data).

Observed growth rates and yields in the Turangi orchard indicate that yields comparable with well managed New Zealand orchards and average yields in Oregon should be achievable in the Taupo region.

---

5: SFF Project L10-148. Establishing polliniser recommendations and realistic yield data for NZ hazelnut orchards. Funded by the MAF Sustainable Farming Fund, HGANZ, and the Waikato branch of NZTCA.

6: Characteristics of Appleby are very similar to the Spanish variety, Negret.

7: The Australian nuts are probably nuts imported into Australia and re-exported to NZ.

## 5: Characteristics of the New Zealand and world markets for hazelnuts

### The New Zealand hazelnut industry

The 2007 Agricultural census revealed that New Zealand has just over 400 hectares of land planted in hazelnuts. These plantings are dominated by a single variety, Whiteheart. A survey by the Hazelnut Growers Association of NZ (HGANZ) in 2002 showed that Whiteheart made up approximately 85% of all trees planted and nearly all plantings since that survey are of Whiteheart plus polliniser varieties. Whiteheart has been promoted because of its high quality round kernel and excellent blanching qualities.

Most hazelnut plantings are on small blocks with hazelnuts being the only commercial crop grown. The size of a "typical" orchard has changed over the last 15 years as the industry has moved from an experimental crop towards a crop with proven commercial potential. Data collected from attendees at a seminar on growing hazelnuts held in Christchurch in 1996 (McNeil 1996) showed that nearly half (45%) of those attending with planted orchards had less than 400 trees planted. Only 21% had large orchards (greater than 1000 trees). In 2009, similar information was gathered by the author from attendees at 5 pollination workshops held in the South Island. This revealed that just 31% now had small orchards (less than 400 trees) whereas over half (53%) now had orchards of more than 1000 trees.

Many of these large new orchards were planted as a result of seminars, such as that organised in 1996 that used the results from trials at Lincoln University to promote hazelnuts as a profitable crop to grow. These large orchards planted after 1996 are starting to produce large crops and growers are now facing issues with the efficient harvesting and marketing of this crop. No data exists of the current level of planting but discussions during HGANZ field days indicate an average annual planting rate of 20,000 to 30,000 trees has fallen significantly since 2008.

The main group representing hazelnut growers is the Hazelnut Growers Association of New Zealand (HGANZ). This has similar aims and functions to the Hazelnut Growers of Australia. Details can be viewed on the website www.hazelnut-growers.org.nz. Membership at the end of 2010 was about 100 members. In the past few years one summer field day has been held each year plus a weekend gathering during Queen's Birthday weekend in the first weekend in June. The AGM is held during the June weekend gathering. Information is disseminated via the website and a quarterly newsletter. The newsletter is distributed in a magazine, Health in a Shell, produced four times a year by NutNZ, a group representing the hazelnut, walnut, and chestnut groups.

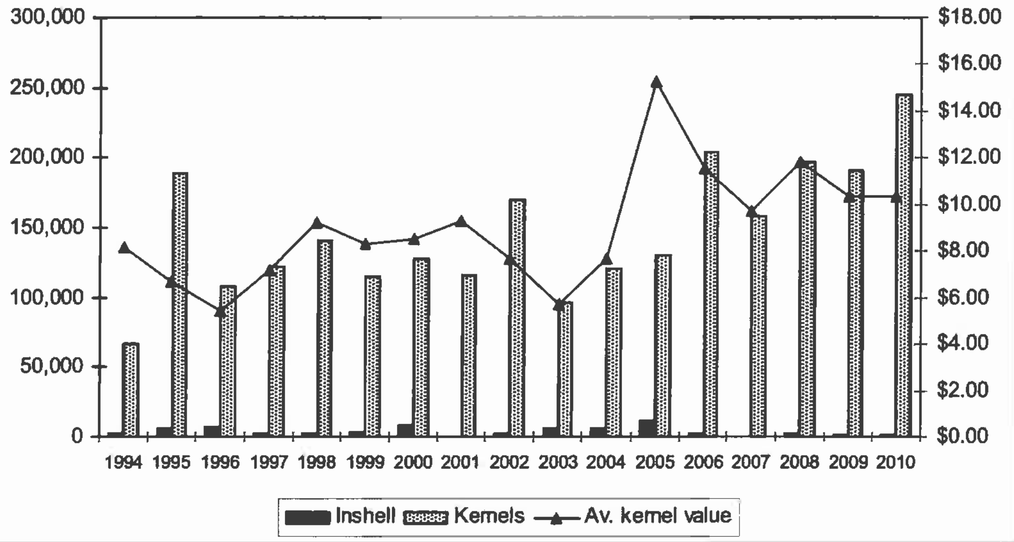
New Zealand has one large processing plant owned by a grower's co-operative (The Hazelnut Company) with about 100 members. Located on the Canterbury Plains in the middle of the main hazelnut growing area, it has a capacity to process 126 tonnes annually using the existing machinery. There are at least ten smaller grower-processors who usually sell through the Farmers Markets that now exist in most urban locations. Most also offer internet sales. These include Uncle Joe's Nuts (Marlborough), Fantail Grove (Wairarapa), Nutt Ranch (Marlborough), Totara Lowlands (Oamaru), and Nutlands (Southland). Internet sales have seen small quantities are exported to Australia, United States, and Europe.

### The New Zealand market

The local New Zealand market for hazelnuts is small but increasing. Trends in hazel imports into New Zealand are shown in Fig 3. Most hazelnuts are imported from Turkey but large quantities are also imported from USA, Italy and Australia[7]. Any expansion of NZ hazelnut consumption is likely to be limited by small population size, lack of consumer familiarity with hazelnuts, and constraints on disposable household income. The trees on the 430 hectares already planted, once in full production, will be capable of producing between 650 and 1300 tonnes per annum. This exceeds the current hazelnut importation of between 200 and 250 tonnes. Any additional large scale plantings of hazelnuts will therefore need to plan to supply export markets.

Discussions with New Zealand processors indicate that there is definite overseas interest in New Zealand hazels and hazel products (including hazelnut oil) but the quantities required for testing these overseas markets exceed the volume available from the industry. The industry needs to find a way to increase its size to develop these markets without flooding the local market while this capacity is developed.

**Fig 3. NZ Hazelnut Imports (kg) and Average Per Kilogram Value of Imported Kernels ($NZ/kg)**

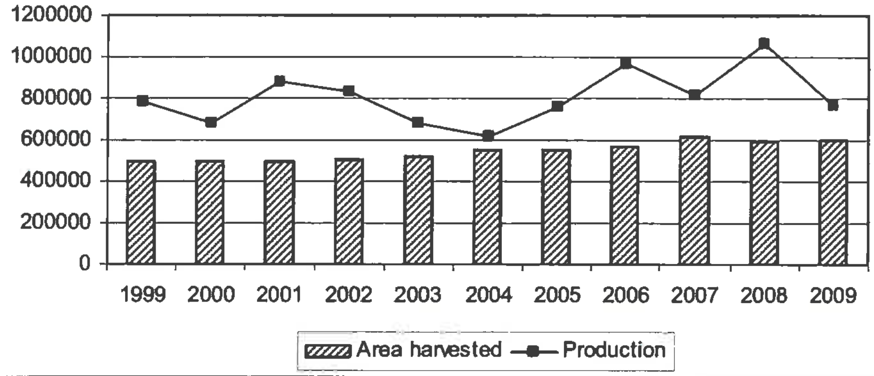



## Trends in world hazelnut production and consumption

Hazelnuts are the one of the five most commonly traded nut crops, along with almonds, walnuts, pistachios, and cashews. According to FAO data, total world nut production increased at about 4.3% per year over the period 1999-2009. Nut consumption over the same 10 year period rose 3.8% but Calcigani (2011) reports a 5.5 % rise in world nut consumption over the last 7 years. Nut consumption has been boosted by increased knowledge of the health benefits of nut consumption and increased consumption of nuts in China and India. China is now a significant importer of all nut species (Kay, 2011).

The area in hazelnuts increased 21% in the period 1999-2009 (FAO data) but the total hazelnut crop continues to fluctuate widely (Fig 4), affected by a strong biennial bearing pattern and the dominant influence of the Turkish crop. The yields achieved from the new planted areas are variable. While the new planted orchards in Oregon can be expected to yield around 3 tonnes/ha (Julian et al, 2009), average yields in new plantings in countries such as Iran, which has experienced one of the largest increases in the area planted, are less than 1 tonne/ha.(Fideghelli et al, 2008).

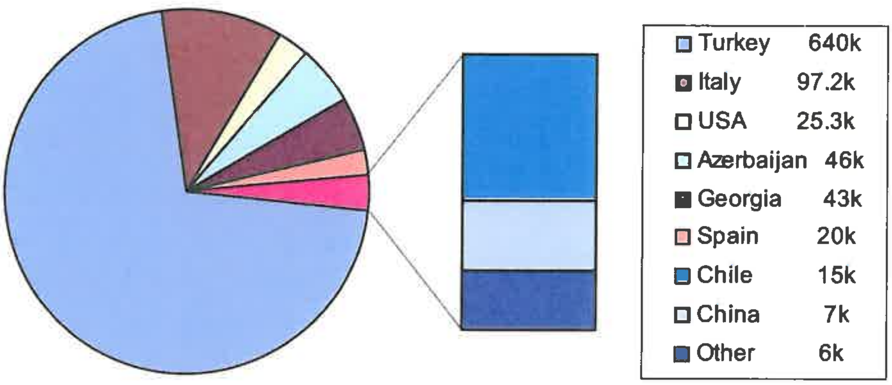
Fig 4. World hazelnut production (inshell, tonnes) and area harvested (hectares) (data from FAO)




Europe is the largest market for hazelnuts. In the 2004-6 period, Germany alone took 26% of traded hazels, followed by Italy (19%), Belgium (8%) and Switzerland (7%) (Calcagni, 2011). Most hazelnuts (95%) are traded as kernels. Despite increased reporting of the health benefits of eating nuts, most hazelnut kernels (95%) are still used in chocolate, baking or confectionery (Kilic & Alkan, 2006).

Despite large plantings occurring in many countries, sentiment among researchers that have visited New Zealand (B Baldwin (2006), J Olsen (2010), P Grau (2011)) is that demand is likely to keep pace with increased supply. Some of the largest increases in area planted have been in areas such as Georgia and Azerbaijan that still use hand harvesting methods and poor quality orchard management practices. There appear to be excellent prospects at the more expensive end of the market for nuts that combine high quality with traceability.

**Fig 5. 2010 Global Hazelnut Production**
(Data from Aman, 2011)




**Turkey**
World hazelnut production is dominated by Turkey, which produces about 70% of the world production (Fig 5). Hazelnut production in Turkey has expanded over the last 30 years under a regime of state subsidies for hazelnut production. (Bayramoglu, 2010). Large areas are produced in mountainous country with small holdings (often about 1 hectare in size) and low production

(less than 1 tonne/ha.) Most of the crop is hand picked and spread to dry outside on the ground. Quality is variable, with possible mould and aflotoxin development due to the weather-dependent drying methods.
The Turkish government has now removed price support for the hazelnut crop and is actively encouraging the abandonment of the small mountainous farms. So far these policies have not resulted in any significant removal of trees (USDA 2011b). Recent low crops due to cold climatic conditions have enabled the sale of stockpiled nuts and prices for Turkish nuts have trended upwards.

**China**

China is now a significant consumer of inshell hazelnuts where they are sold as a high value snack item. The preferred method of use involves partly cracking the shell and soaking the nut in flavoured brines (Aman, 2011). Chinese imports of all nuts have soared over the last 2 years and hazelnut imports have followed that trend (Fig 6).

New Zealand already has all the main inshell varieties supplied by the Oregon industry to China (Ennis, Barcelona, and Jefferson) and the opportunity exists for New Zealand grown hazelnuts to supply this market. Ennis is very susceptible to Eastern Filbert Blight and is in rapid decline in Oregon. It remains one of the best quality inshell varieties in the world due to its high yield, large nut size, and thin shell with an attractive pale striped shell colour. There is an opportunity to export NZ grown Ennis into the Chinese or American markets to replace the declining supply of Ennis nuts from Oregon orchards. There have been problems achieving high yields of good quality Ennis nuts in some cooler parts of New Zealand and more research needs to be done to identify the best growing areas.

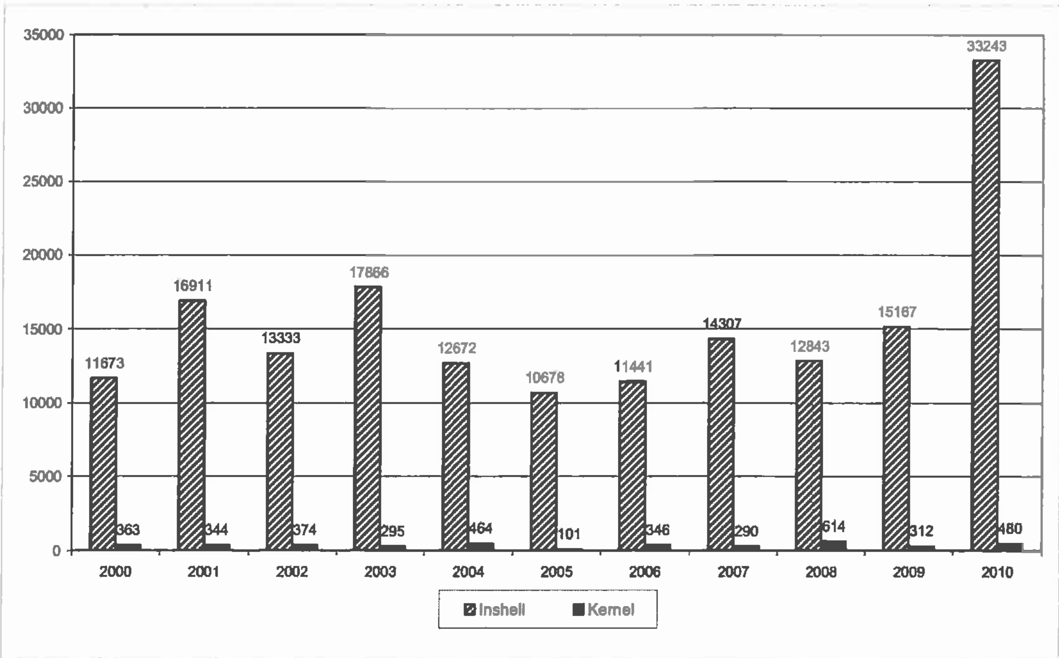



Fig 6. Hazelnut imports into China, 2000 - 2010 (metric tons).
(Data from Kay, 2011)

**Australia.**

Australia has a large and expanding nut industry. It is estimated that nut orchards planted or planned by 2007 will produce crops worth more than 1 billion Australian dollars by 2015 (ANIC 2007). Annual Australian nut consumption has risen from 34,000 tonnes (approx.) in 2002/3 to about 46,000 tonnes in 2009/10 (Joyce, 2011).

The largest nut industries in Australia are those suited to hot Mediterranean climates (almonds, walnuts, pecans, pistachios) or humid subtropical climates (macadamias). Hazelnuts, more suited to cool temperate climates, are a small part of the Australian nut industry with an estimated 300 hectares planted (ANIC 2010). This is projected to rise to about 400 hectares by 2015, producing about 1000 tonnes of nut inshell. Annual imports of hazelnuts into Australia amount to about 100 tonnes inshell and 2000 tonnes of kernel (ANIC, 2009), double the anticipated crop produced from Australian orchards. These figures indicate that there is an opportunity for New Zealand hazelnuts to replace some of the hazelnuts currently imported into Australia.

**Chile.**

Large scale planting of hazelnuts in Chile has been encouraged by the Italian confectionary company, Ferrero, who have planted 3000 hectares of their own orchards there. The area planted in hazels in Chile has increased from 3580 hectares in 2005 to 12,000 hectares in 2011. Approximately 1000 hectares are planted each year (Grau, 2011). The main varieties planted are Tonda di Giffoni (for the kernel market) and a "Barcelona" type (the genotype differs slightly from the typical Barcelona grown in Oregon) for the inshell market (pers. comm. P. Grau, 2011). Growers in Oregon are aware of the rapid increase in the plantings in Chile and expect Chile to overtake them in production of inshell nuts by 2020 (Keely, 2010, Fig.7).

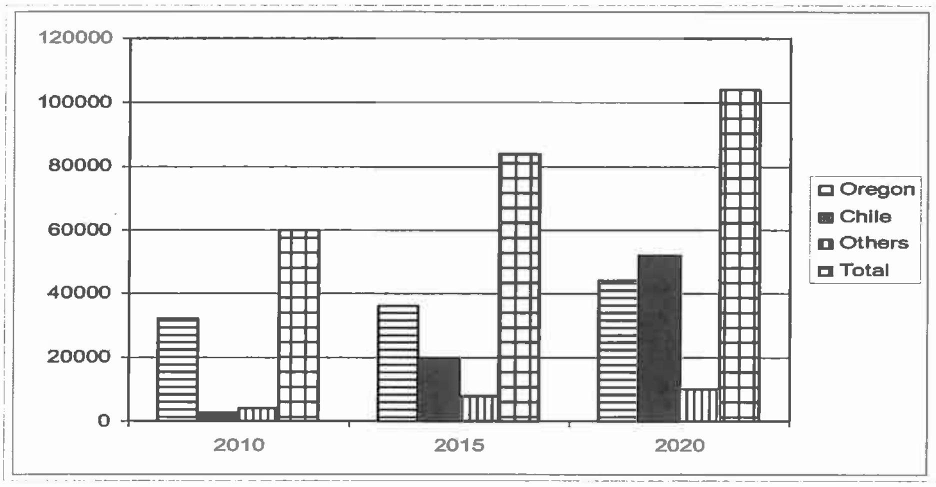



Fig 7: Predicted 10 year supply growth of inshell hazelnuts (From Keely, 2010).

**Ferrero**

Ferrero is the fourth largest confectionary company in the world. They are the largest single purchaser of hazelnuts in the world, taking about 20% of the world's annual production. They are planning for an additional 30-40% growth in their hazelnut requirements over the next 10 years and are planting orchards in several countries (Casale, 2011). They have 940 acres in Argentina, 7400 acres in Chile, and 1730 acres are under development in South Africa. They plan to plant 6420 acres in Georgia in a scheme that also gains carbon credits. They are working with researchers in Canada who are attempting to develop hazelnut plantings there (pers. comm. W. Glen, 2011).

In all the countries where Ferrero have planted orchards, they have also encouraged and assisted local land owners to plant hazels and set up local hazel grower's associations[9]. The Ferrero Group see the benefits of developing their own orchards and co-operating with local growers close to their factories as being: freshness of product; traceability; better communication with producers; and greater sustainability, especially the fuel savings due to lower transport distances (Pisetta, 2011). They are also concerned about future risk-free supplies, citing Turkey as a source of hazelnuts where the quality of the kernels cannot be guaranteed due to variable and primitive production methods (Casale, 2011).

Ferrero has a processing factory in Australia (in Lithgow, New South Wales) and have investigated growing hazelnuts in Australia (B. Baldwin, pers. comm.) This factory offers a potential market for New Zealand grown nuts if nuts of suitable varieties and quality can be produced. The varieties preferred by Ferrero are Tonda Gentile delle Langhe, Tonda di Giffoni, and Tonda Romana.

---

9: See http://www.ferrerohbd.com/fc-796/

## Conclusions and suggestions for further research

The climate of most of the Lake Taupo catchment is suitable for commercial hazelnut production. The potential for damage from frosts in November and December exists, but is no greater than for other hazelnut growing areas in New Zealand. The available data indicates that the frequency of late frosts is unlikely to significantly affect the profitability of hazelnut cropping in the areas most suitable for commercial production.

The quality of nuts produced in 2011 in the two orchards examined had high levels of mouldy kernels in varieties that are known to be susceptible to mould. It is recommended that varieties selected for planting on the western side of the Lake Taupo catchment should have a low susceptibility to mould. Similarities in the quality of nuts from Turangi and Wairata suggest that nut quality analyses of nuts from Wairata could be used to select varieties suited to the Taupo region. Further research is needed to determine the quality of nuts from varieties susceptible to mould grown on the drier eastern side of the Lake.

Approximately 4800 hectares of Class 3 land could be considered as having good potential for hazelnut production with only slight or moderate limitations to economic development. This is all farmland, mapped on the Waikato Regional Council website as having "very versatile" soils, and currently in pasture.

There are also a further 4300 hectares of Class 3 land suitable for growing hazels that may have economic limitations to profitable hazelnut production because it is planted in exotic forests, is located on the western edge of the catchment isolated from other potential growing areas, or has potential for subdivision for urban or peri-urban development

It is considered that all class 4 land will have significant limitations to economic development into hazelnut orchards.

European studies suggest that hazelnut growing with commercially acceptable yields should be possible with nitrogen fertilizer applications containing up to 75 kg per hectare of nitrogen. At this rate of nitrogen application, hazelnut production is a permitted activity under the Section 5 rules implemented by the Waikato Regional Council. Changing land use from livestock farming to hazelnut growing results in a decrease in leached nitrogen. Landowners with existing Nitrogen Discharge Allowances who plant some of their land into hazel orchards can sell or lease the extra nitrogen allowance created or use it to increase stocking rates on other parts of the farm.

The gross margin for hazelnut production in the Lake Taupo catchment is estimated at about $4800 per hectare, assuming the production levels and processing costs are similar to those achieved in Oregon, USA, and a price of $3/kg. This is similar to estimated returns for hazelnut production in Australia, Oregon, and Italy. If these returns can be achieved, they exceed the gross margins from most livestock based farming systems and are significantly higher per kilogram of leached nitrogen. Costs of harvesting and processing the hazelnuts ready for sale are uncertain as the facilities do not exist in the North Island at present. It is possible that gross margins could range from less than $2500/ha (small scale, inefficient harvesting/processing systems) to more than $8500/ha (efficient harvesting/processing systems, new productive varieties).

While the area of hazels already planted in New Zealand has the ability to supply the current New Zealand consumption of hazelnuts, potential export markets exist in Australia (including supply to the Ferrero factory there) and China. The Chinese market, which buys mainly in-shell hazelnuts, offers potential for areas like Taupo that do not yet have easy access to nut cracking facilities if they can successfully grow suitable varieties.

If landowners with land suitable for commercial hazelnut growing in the Lake Taupo area decide to plant hazelnuts, the following research is recommended.

1: Hazelnut markets in Australia and China should be investigated to determine the characteristics of these markets, the nut quality required, and any opportunities for supply by New Zealand hazelnuts. The nut quality is especially important as it guides the selection of varieties to plant.

2: Trials should be established to determine the varieties most suited to the Lake Taupo catchment. These trials should compare productivity (yield and yield efficiency) and nut quality. Varieties trialed should include Barcelona, Ennis, Lansing and Jefferson for the Chinese in-shell market and Tonda di Giffoni, Tonda Romana, Tonda Gentile delle Langhe, Appleby, and Whiteheart for kernel markets.
Nut quality assessments could start immediately using nuts from the Turangi orchard, supplemented with nuts from the Wairata Forest Farm Variety Collection.

3. New trials could also include plots examining the nitrogen leaching characteristics of hazelnut orchards. These plots could be used to examine the efficiency of various forms of nitrogen fertilizer and yield response to various application rates to determine the optimum application rates.

4. The trials should test the effect of irrigation on yields on the main soil types planted to determine the requirements for orchards on the pumice soils.

5. Research is required to determine the best grass/legume species mix for the orchard floor taking into account the requirements for harvesting and control of soil erosion.

6. If landowners wish to integrate livestock grazing or irrigate with effluent, research will be required to determine whether levels of coliform bacteria at harvest can be maintained at acceptable levels.

Results from any research into hazelnut growing will be applicable to the wider Volcanic Plateau region, especially the Rotorua Lakes area. Collaboration with Environment Bay of Plenty and other regional authorities within this wider area would be beneficial by enabling access to additional funding sources for research and industry development.

## Literature Cited:


AgriGeorgia. 2010. PDD – Afforestation with Hazelnut Plantation in Georgia. Downloaded from: http://www.climateprojects.info/chameleon/outbox//9b5b4ccf1878b51c58d2d10216e8cf28/PDD_HAP_CFS.pdf

AK Consultants Pty Ltd. 2011. Enterprise Profile – Hazelnuts. Downloaded 31/1/2012 from http://www.dpiw.tas.gov.au/inter.nsf/Attachments/JBAS-MY9HA/$FILE/WfW_EnterpriseProfile_Hazelnuts.pdf

Aman T. 2011. World Crop Overview. Proc. 96th Annual Meeting of Nut Growers Society of Oregon, Washington & Brit. Columbia; 26-30.

ANIC. 2007. Australia's Nut Industry. A case for high priority in export market development and export market success. 20p. Downloaded from www.dfat.gov.au/trade/export_review/submissions_recieved/AusNutIndustryCuncil.pdf

ANIC. 2009. Australia's Nut Industry. Growing for success. Downloaded 19/10/11 from: www.nutindustry.org.au/files/ECGU6KF5N4/Australia_s_Nut_Industry_-_2009.pdf

Baldwin, B. 2010. Hazelnuts: Variety assessment for south-eastern Australia. RIRDC publ. No. 09/178.

Bayramoglu Z., Orkan Ozer O., Gundogmus E., Fusan Tatlidil F... 2010. The impact of changes in Turkey's hazelnut policy on world markets. African Journal of Agricultural Research 5(1):7-15. Also online at http://www.academicjournals.org/AJAR

Bergoughoux F., Germain E., and Sarraquigne J-P. 1978. The Hazelnut. Production and Culture. INVUFEC: Paris (Translated by J.J.M. Leerschool). 98p

Bignami C., Cammilli C., Moretti G., and Sallustri L. 2005. Growth analysis and nitrogen dynamics in hazelnut Tonda Gentile Romana. Acta Hort 686: 193-200.

Braun L.C., Gillman J.H., Hoover E.E., Russelle M.P. 2011. Nitrogen fertilization for new plantings of hybrid hazelnuts in the Upper Midwest of the United States of America. Canadian Journal of Plant Science 91(4): 773-782.

Brown E. and Haigh A. 2004. Future water demand from pasture irrigation in the Waikato Region. Environment Waikato Technical Report 2005/01. 30p.

Calcagni P. 2011. Nuts and Dried Fruits: World Market Trends. Downloaded 23/11/11/ from http://vinacas.com.vn/images/File/10June_Pino_INC.pdf

Casale A. 2011. Ferrero Group – Hazelnut Business Development (HBD). Global production systems for hazelnuts. Presented at 2nd Ann. Ontario Hazelnut Conference, March 23rd, 2011 at Simcoe, Ontario. Downloaded 22.6.11 from: http://www.erieinnovation.com/downloads/casale.pdf

Chaplin M.H. and Dixon A.R. 1979. The development of standard ranges for leaf nitrogen in the filbert. J. Amer. Soc. Hort. Sci. 104:710-712.

De Salvador F.R., Proietti G., Lolletti D., Delfini M., Di Cocco M.E., Tombesi A., and Farinelli D. 2009. Influence of pedoclimatic conditions and orchard management on fruit quality in hazelnut cultivars "Tonda Gentile Romana" and "Tonda di Giffoni". Acta Hort. 845: 599-606.

DPIPWE. 2011. Hazelnuts Gross Margin & Profitability Analysis. Downloaded 31/1/2012 from http://www.dpiw.tas.gov.au/inter.nsf/WebPages/LBUN-8M589T?open

Environment Waikato. 2003. Protecting Lake Taupo: A long term strategic partnership. Environment Waikato, Hamilton. 28p.

Fideghelli C and De Salvador F.R. 2009. World Hazelnut Situation and Perspectives. Acta Hort. 845: 39 – 51.

Goh K.M., Ridgen G.E,, Daly M.J. Biological nitrogen fixation and biomass production in the understorey vegetation of an organic apple orchard in Canterbury, New Zealand. Downloaded 13/12/11 from: http://www.hortnet.co.nz/publications/proceedings/ifoam/ifoam11.htm

Joyce C. 2011. 2011. Better with nuts. Downloaded 4/11/11 http://nutindustry.org.au/files/D1I4WQSBHO/1_1_Chris_Joyce_ANIC_2011_presentation.pdf.

Julian J., Seavert C., Olsen J. 2008a. Enterprise Budget: Hazelnut, Willamette Valley Region. Oregon State University Extension Service publ. EM 8556.

Julian J., Seavert C., Olsen J. 2008b. Orchard economics: The costs and returns of establishing and producing hazelnuts in the Willamette Valley. Oregon State University Extension Service publ. EM 8748-E.

Julian J., Seavert C., Olsen J. 2009. An economic evaluation of the impact of Eastern Filbert Blight resistant hazelnut cultivars in Oregon, USA. Acta Hort. 845: 725-731.

Keely D. 2010. President's Welcome: Ensuring a future 2010 and beyond. Proc. 95th Ann. Meeting of Nut Growers Society of Oregon, Washington, and Brit. Columbia: 10-12.

Kilic O. and Alkan K. 2006. The developments in the world hazelnut production and export, the role of Turkey. Jnl of Applied Sciences 6(7):1612 – 1616.

Ledgard S.F., Thorrold B.S., Petch R.A., Young J. 2001. Use of Overseer as a tool to identify management strategies for reducing nitrate leaching from farms around Lake Taupo. Downloaded 16/12/11 from: www.overseer.org.nz/OVERSEERModel/Information/References.aspx

Lynn IH, Manderson AK, Page MJ, Harmsworth GR, Eyles GO, Douglas GB, Mackay AD, Newsome PJF. 2009. Land Use Capability Handbook – a New Zealand guide for the classification of land 3rd Ed. Hamilton, Agresearch; Lincoln, Landcare Research; Lower Hutt, GNS Science. 163p.

McNeil D.L. 1996. An Overview of the New Zealand Temperate Nut Industries and Research Developments over the last Five years. Report to NZ Tree Crops Association. 11p.

MAF. 2011. A Guide to Forestry in the Emissions Trading Scheme. Ministry of Agriculture and Forestry, Wellington. May 2011. 45p. Downloaded from: http://www.maf.govt.nz/forestry/forestry-in-the-ets

Mehlenbacher S.A. 1991. Hazelnuts (*Corylus*) In: Genetic resources of Temperate Fruit and Nut Crops. Acta Hort., 290: 791-836

Mehlenbacher S.A. 2002. Hazelnuts in Georgia and Azerbaijan. Proc. 87th Ann Meeting of Nut Growers of Oregon, Washington, and Brit. Columbia: 42 – 59.

Mehlenbacher S.A. 2009. Release of 'Jefferson' Hazelnut (OSU 703.007) and pollinizers 'Eta' and 'Theta'. Proc. 94th Ann. Meeting of Nut Growers Soc. of Oregon, Washington and Brit. Columbia: 57-63.

Menneer, J.C., Ledgard, S.F. and Gillingham, A.G. 2004. Land Use Impacts on Nitrogen and Phosphorus Loss and Management Options for Intervention. Client Report Environment Bay of Plenty.

Olsen J. 2001. Nutrient Management Guide: Hazelnuts. Oregon State University Extension Service publ. EM 8786

.
Available at extension.oregonstate.edu/catalog/pdf/em/em8786-e.pdf

Olsen J. 2002. Growing Hazelnuts in the Pacific Northwest. Oregon State University Extension Service publ. EC1219. 47p

Olsen J., Sanchez E., Righetti T. 2001. Absorption and distribution of isotopically labeled nitrogen in the hazelnut tree following ground and foliar applications. Acta Hort 556: 437 – 444.

Pisetta M. 2011. Hazelnut Business Development Strategy. Presented at 2nd Ann. Ontario Hazelnut Conference, March 23rd, 2011 at Simcoe, Ontario. Downloaded 23/6/11 from: http://www.erieinnovation.com/downloads/pisetta.pdf

Redpath M. 2011. The identification of hazelnut varieties in New Zealand. Part 2 of SFF project L08-088. 42p.
Available at http://hazelnut.org.nz/variety/L08-088_Hazelnut_Report_7.pdf

Rijkse W.C. and Guinto D.F. 2010. Soils of the Bay of Plenty. Vol. 3: Eastern Bay of Plenty. Environment Bay of Plenty Environmental Publ. 2010/11-3.

Roversi A. and Ughini V. 2005. Further investigations into the mineral uptake of hazelnut orchards. Acta Hort 686:285 – 289.

Thorrold B. 2006. Final Report: *New profitable farming systems for the Lake Taupo catchment.* Prepared for Puketapu Group.

Tous J., Romero A., Plana J., Sentis X., Ferran J. 2005. Effect of nitrogen, boron and iron fertilization on yield and nut quality of 'Negret' hazelnut trees. Acta Hort. 686:271-280.

TÜV SÜD Industrie Service GmbH Carbon Management Service. 2011. Validation of the Project "Afforestation with Hazelnut Plantations in Western Georgia" according to the CarbonFix Standard version 3.0. Report No. 1484934.
Downloaded 21/12/2011 from: http://get-carbon.com/Validation_HAP.pdf

USDA FAS. 2011a. Italy Tree Nuts 2011. US Foreign Agricultural Service Gain Report No 17 1148. 9p. Downloaded 19/10/11 from: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Italy%20Tree%20Nuts%202011_Rome_Italy_10-5-2011.pdf

USDA FAS. 2011b. Turkey Tree Nuts, Annual, 2011. USDA FAS GAIN report. 19 October, 2011. 10p. Downloaded 23/11/11 from: http://gain.fas.usda.gov/Recent%20GAIN%20Publications/Tree%20Nuts%20Annual_Ankara_Turkey_10-19-2011.pdf

Waikato Regional Council. 2007. Variation 5 – Lake Taupo catchment. Operative Version. Waikato Regional Council, Hamilton. 57p.

# Appendix 1.
# Estimated costs and returns of establishing and producing hazelnuts in the Lake Taupo catchment.

Assumptions used in this analysis are listed below. Figures for yields and time required for orchard operations have been taken from Oregon figures (Julian et al, 2008). New Zealand costs have been taken from the Lincoln University Financial Budget Manuel 2010 unless otherwise stated. Where costs vary between regions, figures applicable to the Waikato (where available) have been used.

These costs are estimates only and each landowner should substitute their own local figures to calculate the costs and returns for their situation.

**Assumptions:**
1: It is assumed that 20 hectares are planted. All costs and returns are converted to a per hectare cost.

2: Trees are planted at a 6 metre row spacing with trees 3 metres apart within the row (435 trees/ha). Tree numbers are based on one hectare sheltered blocks with 8 metre headlands at the end of rows and rows 8 metres in from shelterbelts. Every second tree is removed at canopy closure, assumed to occur in the eleventh year. Full production occurs in year 12.

3: Two year old ($2^{nd}$ leaf) trees are planted. Tree cost is $14, including any Plant Variety Right royalties. Tree losses in the first year are 5% of initial planting. Tree planting costs calculated using rates for forestry planting of container stock. Tree stems are painted with white water based paint at planting, with labour costs similar to planting costs plus paint costs at $50/ha.

4: General labour costs are $18/hr.

5: Field preparation consists of spraying out the planting sites. It has been assumed that areas to be planted are already protected by shelter belts and the cost of establishing shelter is not included in the budget.

6: The hazelnut price is $3/kg. This is lower than returns achieved by growers in NZ and Oregon at present but is realistic if current world prices are maintained.

7: Production trends follow those achieved in Oregon, USA with high yielding varieties. Average annual production of a mature orchard is 2500 marketable kilograms per hectare. Commercial yields begin in the third year and full production is reached in year 12.

8: A 75 horsepower 4-wheel-drive tractor is used for harvesting, spraying, and orchard flailing work. A smaller 50 horsepower tractor can be used for applying fertilizer and general orchard work during harvest (Lifting bins, etc). It is assumed that farmers will already own a suitable 75 horsepower tractor.

9: Mowing costs calculated at $85/ha using contractors. Mowing is done monthly from September to April (8 months). This is more frequent than in most orchards but may be necessary to keep the sward short and dense to avoid soil erosion and provide a suitable surface for harvesting.

10: It is assumed that fertilizer is applied annually as a solid general horticultural fertilizer such as Nitrophoska Blue TE. Fertilizer is applied by hand up until year 5 and using a tractor mounted spreader thereafter. Costs of hand applying fertilizer are based on forestry rates for hand application (35c/tree). Tractor mounted spreading based on covering 6 hectares/hr.

Fertilizer rates used are based on recommendations for nitrogen application from the Hazelnut Nutrient Management Guide published by the Oregon State University up to an application rate equivalent to 75 kg N/ha. Cheaper fertilizer options may be possible based around correcting specific nutrient deficiencies based on soil and leaf tests.

11: Boron is applied with the solid fertilizer applications (B is included in Nitrophoska Blue TE and most other horticultural blends). Additional boron will probably be required in mature orchards. It is assumed that this will be applied as solid fertilizer using products such as Nitrophoska Blue TE + B + Mg (Ravensdown) at a similar cost to Nitrophoska TE.

12: Lime is applied prior to planting at 5 tonnes/ha and every 5 years at a rate of 2 tonnes/ha.

13: Soil tests are conducted every 5 years starting with year 1. Leaf analyses are done every 3 years starting with year 4.

14: Autumn applications of copper fungicides for control of bacterial blight are made using a knapsack every autumn for the first three years.

15: Sucker control starts in year 2, with 4 control sprays each year. Chemical costs based on 0.5 litre of Buster per hectare per year. It is assumed that sucker control will be by knapsack application. In mature orchards, sucker control is usually carried out in conjunction with herbicide application.

16: It is assumed that vegetation in the tree rows will be controlled by herbicides using knapsack application in the first 5 years. Boom sprayers are used once trees are large enough (year 5). The spray strip will be limited to 1 metre width. Chemical costs are assumed to be one sixth of rates used for spraying out the complete area, with similar application time costs.

17: Costs have been included for suppressing grass growth with a low concentration herbicide application prior to harvest. This is not normal practice in hazelnut orchards but has been included here to recognize the possible need to maintain a vigorous grass sward on the sandy Taupo soils. Costs have been calculated on application of Roundup at 200 mls/ha (chemical topping rates). Quoted application costs vary from $27/ha to $48/ha (contracted spraying for seedbed preparation, Gisborne). The higher figure has been used.

18: Harvest costs are estimated at $300/tonne assuming that tractor mounted sweeper-type harvesters are used rather than hand operated vacuum harvesters. This is similar to grain harvesting costs ($250 to $300/tonne). Australian figures (Baldwin 2010) place harvesting costs at $2000/ha using contractors and hand operated vacuum harvesters. Oregon figures are around $US150/ha using sweepers and tractor mounted harvesters.

19: Freight costs to the driers are charged at $50/tonne (150 km to drier).

20: Washing and drying costs are calculated using Oregon rates of about 10 cents per kg. This is nearly double the maize drying charges quoted but allow for a cost for washing the nuts prior to drying.

21: No costs are included for control of insect pests. Green shield beetles (*Nezara viridula*), grass grub beetles (*Costelytra zealandica*), bronze beetles (*Eucolaspis brunnea*), aphids (*Myzocallis coryli*), and scale have caused localized problems in some regions of New Zealand but regular control is not necessary in most orchards. No significant damage from these pests was noted in the Taupo orchards.

## Economic costs and returns for establishing a hazel orchard (6 metre x 3 metre spacing) in Taupo based on Oregon growing systems

| Income | Yr1 | Yr 2 | Yr 3 | Yr 4 | Yr 5 | Yr 6 | Yr 7 | Yr 8 | Yr 9 | Yr 10 | Yr 11 | Full Prod |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Yield (kg/tree) | 0 | 0 | 0.3 | 1 | 1.8 | 2.5 | 4.5 | 4.5 | 5.0 | 5.8 | 4.8 | 5.7 |
| Yield (kg/ha) | 0 | 0 | 130 | 435 | 783 | 1088 | 1958 | 1958 | 2175 | 2523 | 2088 | 2500 |
| Price ($/kg) | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| **Gross income ($/ha)** | **0** | **0** | **390** | **1305** | **2349** | **3263** | **5873** | **5873** | **6525** | **7569** | **6264** | **7500** |
| **Variable costs:** | | | | | | | | | | | | |
| Trees | 6090 | 308 | | | | | | | | | | |
| Plant trees | 653 | 33 | | | | | | | | | | |
| Paint trees | 703 | 35 | | | | | | | | | | |
| Fertilizer | | | 27 | 27 | 34 | 40 | 46 | 46 | 46 | 46 | 46 | 46 |
| Fertilizer application-labour | | 152 | 152 | 152 | 152 | | | | | | | |
| Lime (applied) | 225 | | | | | 225 | | | | | 225 | 45 |
| Nutrient analysis | 3 | | | 4 | | 3 | | 4 | | | 3 | 4 |
| Mowing | 680 | 680 | 680 | 680 | 680 | 680 | 680 | 680 | 680 | 680 | 680 | 680 |
| Weed control | 76 | 76 | 76 | 76 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| Sucker control | | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 | 114 |
| Pruning | | 261 | 261 | | | | 653 | 653 | 653 | 653 | 653 | 653 |
| Shelter trimming | | | | | 500 | | 500 | | 500 | | 500 | 250 |
| Pest control | | | | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 | 28 |
| Pre-harvest grass sprayout | | | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 | 50 |
| Harvest costs | | | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 | 300 |
| Freight | | | 7 | 22 | 39 | 54 | 98 | 98 | 109 | 126 | 104 | 125 |
| Washing and Drying | | | 13 | 44 | 78 | 109 | 196 | 196 | 218 | 252 | 209 | 250 |
| Tree clearance (yr 11) | | | | | | | | | | | 2440 | |
| **Total direct costs ($/ha)** | **8429** | **1659** | **1680** | **1497** | **2027** | **1654** | **2715** | **2219** | **2748** | **2300** | **5403** | **2596** |
| | | | | | | | | | | | | |
| **Net projected returns ($/ha)** | **-8429** | **-1659** | **-1290** | **-192** | **322** | **1608** | **3157** | **3653** | **3777** | **5269** | **861** | **4905** |
| Cumulative cash flow | -8429 | -10088 | -11378 | -11570 | -11247 | -9639 | -6481 | -2828 | 949 | 6218 | 7080 | 11984 |

Notes: Year 11 costs include costs of removing every second tree.

Costs for lime application and shelter trimming are converted to an annual cost for the full production year column.