



Lessons learnt: Grazed orchards in Northern Ireland

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1 Context

The AGFORWARD research project (January 2014 - December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1. to understand the context and extent of agroforestry in Europe,
2. to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3. to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4. to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report contributes to Objective 2, Deliverable 3.8 which is to describe the lessons learnt from innovations within agroforestry with high value tree systems. Within the project, there were ten stakeholder groups focused on such systems (e.g. grazed orchards, intercropped and grazed olive groves and citrus orchards, and high-value walnut and chestnut plantations). This report focuses on a stakeholder group which focussed on grazed orchards in Northern Ireland.

2 Background

The initial stakeholder report (McAdam, 2014) and the research and development protocol (McAdam 2015) provide background data on grazed orchards in Northern Ireland. McAdam and Ward (2016) provide a detailed description of the system.

The practice of grazing is very rare in the commercial orchards of Northern Ireland. The production of blemish-free apples requires an intensive agrochemical programme. Lavery et al. (2014) estimated that there were 219 growers, managing 1,519 hectares of top fruit orchards in Northern Ireland in 2014. They reported that 1,519 hectares was equivalent to 40,936 spray hectares receiving an estimated 36.5 tonnes of active ingredient. Lavery et al. estimated that 97% of all top fruit crops were grown in County Armagh, with Bramley apple orchards accounting for 99% of the total top fruit grown in Northern Ireland. There were an estimated 38,235 tonnes of Bramley apples harvested in 2014.

By 2016, in contrast with previous surveys, holdings comprising less than 2 hectares were excluded, and Jess et al. (2017) estimated there were approximately 1,526 hectares of top fruit orchards in Northern Ireland in 2016. Of the 215 top fruit holdings in Northern Ireland in 2016, only 138 were above 2 hectares, providing the survey population. Jess et al. (2017) reported that the 1,526 hectares was equivalent to 46,770 spray hectares receiving an estimated 35.5 tonnes of active ingredient. Jess et al. estimated that, 95% of all top fruit crops were grown in County Armagh, with Bramley apple orchards accounting for 97% of the total top fruit grown in Northern Ireland. There were an estimated 44,824 tonnes of Bramley apples harvested in 2016, a 17% increase compared to 2014.

A typical orchard spray programme includes 10 to 12 fungicide applications from May to end of July to prevent the main disease apple scab (*Venturia inaequalis*), two herbicide applications to control weeds in the understory of the trees, and one insecticide application.

Farmers have proposed that control of apple scab and a reduction in pesticide inputs/costs might be achieved by grazing sheep in the orchards. The logic is that sheep will eat apple leaves immediately as they fall to the ground, and help to decompose old leaves by trampling, thus reducing the refuge for the organism responsible (McAdam 2014).

Commercial orchards are mown approximately eight times per year, an activity involving labour and machinery costs. The introduction of livestock to the orchard can minimise the need for such mowing and at the same time it can provide animal feed for sheep production. However the livestock can also incur costs, and bring additional complexity and administrative burdens to top fruit production (Burgess 2014; Corroyer 2014; Durrant and Durrant 2009).

Several questions were posed, regarding sheep grazing in orchards, at the initial stakeholders meeting in Northern Ireland (McAdam, 2014). To obtain quantitative answers a replicated experimental of a split-plot design was carried out in 2015 in an existing orchard planted in 1998. Treatments included four replicates of three crops: dessert apples, cider apples, and a grass control, split into two grass management treatments: grazing or mowing.

Using mixed breed sheep, the initial stock rate was set at three sheep per plot but after eight days it was considered that five sheep per plot was a more appropriate stocking rate for the trial area. Plot sizes in the trial are 0.33, 0.04 and 0.042 hectares for the grassland, grazed orchard and mown orchard plots respectively.

Grass in the orchard has been typically managed by mechanical mowing once per month from March to October. No damage to trees was recorded by this method of management. From 12 May to 17 June 2015, Coet-de-linge, Jonagold and grass plots had a mean of 50, 57 and 57 total sheep grazing days accumulated respectively.

3 Description of system

Table 1 provides a general description of the grazed orchard agroforestry system. A description of a specific case study system is provided in Table 2.

Table 1. General description of the grazed orchard system

General description of system	
Name of group	Grazed orchards in Northern Ireland
Contact	Jim McAdam
Work-package	3: High value trees
Associated WP	Work-package 2 and Work-package 5 (Use of livestock)
Geographical extent	Grazed cider orchards are found in England, Wales, Northern Ireland and northern France.
Estimated area	In 2014 the total area of apple orchards in Northern Ireland was 1519 ha. 99% of the apples grown in Northern Ireland are of the culinary variety "Bramley Seedling" the other 1% is made up of cider and dessert varieties (Lavery et al. 2014). Typical field sizes are between 1.5 and 4 ha.
Typical soil types	Cambisols
Description	Majority of orchards are traditional or "bush" orchard planted in linear rows. Tree spacing varies with rootstock used. M9 dwarfing rootstocks are widely used with spacing of 4 m between rows, 1.5 m between trees. A herbicide strip approximately 2 m wide is maintained in the tree rows while the grass strips between tree rows is mowed regularly. Field boundaries planted with windbreaks or hedgerows of mixed woody species. Area below windbreaks generally left unmown, producing a dense under storey.
Pesticide inputs	Northern Ireland top fruit sector is made up of 99% Bramley apple and 1% other top fruit crops to which 36.5 tonnes pesticides applied per year (Lavery et al. 2014). Pesticide inputs are mainly fungicides to prevent the main disease apple scab (<i>Venturia inaequalis</i>)
Tree species	Apple (<i>Malus domestica</i>)
Tree products	The top fruit industry annually produces about 30-45,000 t product per year of which 12-15% goes to fresh market valued €8.64 million, 60-70% to the added value market (value £7-8 million) and 25-30% to juice and cider production.
Understory Crop	Grasses such as perennial ryegrass
Crop products	Typically grass in orchards is not grazed or cut but maintained by mowing.
Animal species	Traditionally none
Animal products	The grass can be used to fatten lambs or to maintain the weight of ewes
Other services	Eventually apple tree wood can be used as fuelwood.
Regulating services	Trees can provide shade for the sheep in summer and shelter in winter. The sheep can promote nutrient cycling and by eating fallen leaves, can remove a refuge for fungi. Above-ground, the trees will increase carbon storage.
Cultural services	Grazed orchards may change labour requirements for an orchard

Table 2. Description of the specific case study system

Specific description of site	
Area (ha)	0.93 ha
Co-ordinates	54°24'43.2000"N; 6°34'55.5528"W (54.412000; -6.582098)
Site contact	Jim Mc Adam
Site contact	jimmcadam@afbini.gov.uk
Site photograph	

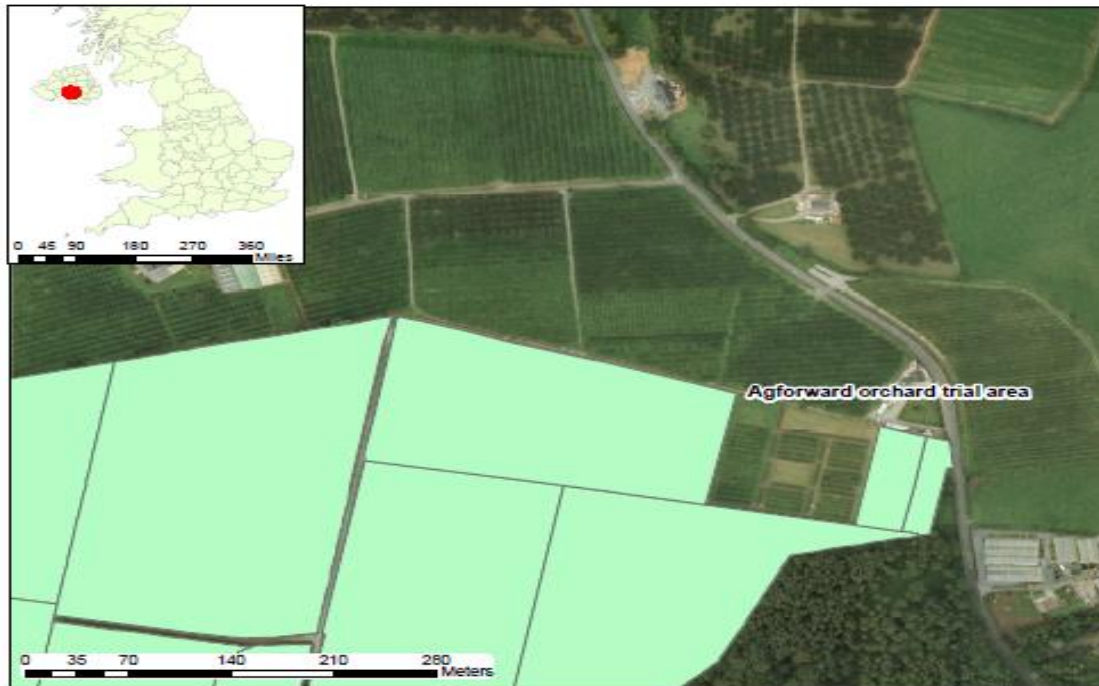


Overview of the AFBI trial plots (2014)



A trial plot area

Map of system



Map of orchard trial area. Mapping material is based upon Crown Copyright and is reproduced with the permission of Land & Property Services under delegated authority from the Controller of Her Majesty's Stationary Office © Crown copyright and database rights.

Experimental aim

Objective	To produce quantitative information about the use of sheep (mixed breeds) to graze cider and dessert orchards in comparison to normal management, mechanical mowing and similar sized grazing plots without trees.
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Climate Characteristics

Mean temperature	13.3°C
Annual precipitation	830 mm (Reference Met Office Climatic data: 1981 – 2010_)
Additional details (e.g. spring frost risk)	Chances of spring frosts average of 37 days frost over the past 30 years from March to May.

Soil Type

Soil type	Eutric Rhodic Cambisol or Pelosol Calcareous brown earth on carboniferous limestone red till. This unusual soil of red limestone (Carboniferous) till covers 3,005 ha, or 0.22% of Northern Ireland (Cruickshank, 1997).		
Soil depth	30 cm		
Soil texture	Clay loam and clay, Clay-rich red soil		
Soil colour	Munsell colour of B horizon is 2.5 YR 4/4 Reddish brown		
Horizon	sand%, silt%, clay%		
Ap	50.6	25.1	24.3
Bw	42.4	14.4	43.2
C	43.3	26.5	30.1
Aspect	Easterly aspect, tending slightly to the South East		
Landscape	This unusual clay-rich red soil is found in the drumlins of Co. Armagh		

	from Loughgall to Armagh City and Navan
Soil characteristics	Refer to Table 4. Available P is adequate in the Ap horizon, but K and Mg are low. The pH is extremely high in B and C horizons, reflecting the high Calcium values and high total of exchangeable bases. The CEC is base saturated. The high loss of ignition value is due to the presence of carbonates. The strong red colour of the soil is not reflected in total iron values. Soil textures are clay loam and clay (clay is 43.2 per cent) in the B horizon. The soil may be classed as a Pelosol.
Tree characteristics	
Species and variety	Apple (<i>Malus domestica</i>) dessert variety Jonagold and Cider Variety-Coet-de-linge
Date of planting	1998
Inter-row spacing	Jonagold 4 m Coet-de-linge 5 m
Inter-tree spacing	Jonagold 1.5 m Coet-de-linge 2 m
Trees per ha	Jonagold 1485 Coet-de-linge 900
Rootstock	Jonagold M9 Coet-de-linge MM106
Tree protection	Trees are supported with a stake to prevent uprooting by wind. A wire mesh is placed around the tree trunk to protect from hare grazing "Hare guard"
Typical apple yield	Typical apple yield are presented in Table 3. Vylupek (2010) quotes a mean apple yield (fresh weight) from UK orchards of 15.7 t ha ⁻¹ . Centre for Alternative Land Use (2007) quotes a yield of 12 t ha ⁻¹ to 20 t ha ⁻¹ . Fairs (2010), quoted by Vylupek (2010) quotes a mature (10 years) yield of about 50 t ha ⁻¹ . Yields can vary substantially between years due to "biennial bearing".
Crop understory management	
Between rows of trees	Grass strips, mowed as for conventional orchard management
Between trees in a row	2 m wide, herbicide strip
Fertiliser, pesticides, machinery and labour management	
Fertiliser	Assumed not modified by grazing
Fungicides	Regular spraying of apple trees during the year to control apple scab (<i>Venturia inaequalis</i>)
Herbicides	Twice per year to manage herbicide strips
Machinery	Tractor access between trees for spraying and mowing applications
Labour	Daily sheep checks for health, welfare, amount of grazing, ensure no damage to trees. Moving of sheep through plots and erecting of temporary fencing. Mowing, Spraying and Harvesting.
Fencing	Permanent around perimeter of the trial area Temporary electric netting between plots
Livestock management	
Species and breed	Sheep: mixed breeds including Texel, Belclare, LLeyn and Highlander
Spring to summer trial	
Date of entry to site	Late April
Date of departure	Mid to late June 56 days before the predicted date of apple harvest
Stocking density	18 ewe lambs, rotated on through plots of 0.47ha
Animal welfare	Sheep need to be checked daily to ensure health and welfare.
Supplementary feed	Sheep may need access to mineral blocks

4 Site description

4.1 Soil chemical composition

The soil chemical composition is described in Table 4.

Table 3. Nutrient analysis for the three soil horizons of the brown earth soil on carboniferous limestone red till at Loughgall, Co. Armagh

Horizon	P (mg kg ⁻¹)	K (mg kg ⁻¹)	Mg (mg kg ⁻¹)	Mg (mg 100 g ⁻¹)	Ca (mg 100 g ⁻¹)	Na (mg 100 g ⁻¹)	K (mg 100 g ⁻¹)	Dithio Fe (mg kg ⁻¹)	Total P (mg kg ⁻¹)
Ap	64	102	85	0.80	15.12	0.09	0.31	16,500	770
Bw	3	99	94	0.89	15.08	0.06	0.30	15,200	841
C	3	91	78	0.64	16.96	0.06	0.22	16,800	1009

Soil horizon	CEC (mg 100 g ⁻¹)	pH	Nitrogen (%)	Carbon (%)	Loss of ignition (%)	Sand (%)	Silt (%)	Clay (%)
Ap	24.42	7.0	0.27	2.92	8.5	50.6	25.1	24.3
Bw	16.88	7.8	0.09	1.28	5.6	42.4	14.4	43.2
C	18.21	8.3	0.06	0.60	7.7	43.3	26.5	30.1

4.2 Apple trees - variety

Apple trees are formed with a combination of a clonal rootstock to give the tree a particular growth habit, and a clonal scion which will determine harvest fruit variety. The majority of orchards in Northern Ireland are “bush” type systems grown on dwarfing rootstock M9. M9 trees require good soil conditions, the ground around the tree clear of weeds and grass, and permanent staking. M9 mature trees grow to 1.8-2.4 m high and have a 2.7 m crown spread (Keepers Nursery). The apple varieties used at this study site are cider “Coet-de-linge” and dessert “Jonagold”. Both varieties are harvested at the end of October/November.

4.3 Apple trees - tree density and height

Both varieties in this orchard were planted in 1998, Jonagold at 1485 and Coet-de-linge at 900 trees per ha, while new commercial cider orchards in the UK tend to be planted at densities of about 600-700 trees per hectare (Vylupek, 2010). Durrant and Durrant (2009) suggested that the cider-maker Bulmers is establishing new orchards planted at a density of 650-750 trees per hectare. Despite this many older orchards are still in use for cider production, and are planted at densities as low as 300 trees per hectare.

The trees received early formative pruning to maintain a single dominant leader followed by regular pruning to thin the canopy. The maintained canopy enables light and air penetration through the tree and allows sprays applied with an air assisted sprayer and to penetrate into the heart of the canopy. Small tree forms (2-3 m high) allow harvesting by hand.

5 Results

Field measurements for the spring/summer trial described in the research and development protocol (McAdam 2015) began in early April 2015 and 2016, and continued until mid-June when the sheep were removed.

5.1 Effect of orchard grazing on trees, yield and fruit quality

Northern Ireland fruit growers are generally very resistant to the concept of sheep grazing their orchards. Their main concerns are the damage to trees resulting in tree mortality and reduced yields.

Observations from a preliminary trial in 2014 highlighted the importance of careful monitoring of grass grazing levels to ensure that the sheep did not graze the trees. In 2014, with low levels of available grass, over one night the sheep removed large areas of bark from the tree trunk and lower larger limbs. In the 2015 trial, even with daily assessments of grass levels one plot (Jonagold) had 13% of the trees with bark damage. All trees in the grazed plots showed signs of lighter branches/twigs getting caught up and tangled in the sheep's wool, leaving strands of wool in the lower canopy (Figure 1). This did not always result in damage as they did not tend to eat this type of material. In all the grazed plots the sheep grazed and stripped the lower branches of leaves and flowers up to 1.14 m from ground level (Figure 1). On one occasion a sheep was observed leaping to catch leaves over 1.14 m.



Figure 1. Grazed orchard, AFBI Loughgall. Ungrazed plots (left-fence removed) show no damage to the lower canopy. Typical effect of sheep browsing in apple trees (right).

5.2 Effect on apple yield

Sheep grazing in the bush apple orchard led to a 23.7% reduction in the apple yield of the cider apple variety Coet-de-linge and a 42.6% reduction in the apple yield of the dessert variety Jonagold over 2015 and 2016. Whilst there was no damage from mechanical mowing, grazing caused damage to trees in the following ways:

- Sheep fleeces caught in the trees caused damage to small branches and twigs.
- Sheep ate all buds and leaves on the apple trees below a height of about 115 cm.
- Even with ample grass, large areas of bark from the tree trunks and lower limbs were removed by the sheep.

Table 4. Mean yields for apple varieties Coet-de-linge (cider) and Jonagold (dessert) on this site from planting in 1998 to 2016

Year	Fresh weight yield (t ha ⁻¹)		Yield Dry weight yield (t ha ⁻¹)	
	Coet-de-linge	Jonagold	Coet-de-linge	Jonagold
1999	0.02	0.46	0.003	0.059
2000	1.38	1.79	0.179	0.232
2001	20.73	22.43	2.694	2.916
2002	4.25	21.49	0.552	2.794
2003	0.44	24.30	0.057	3.160
2004	30.21	40.83	3.927	5.307
2005	18.90	37.11	2.457	4.825
2006	42.50	44.34	5.525	5.764
2007	35.40	21.34	4.602	2.775
2008	36.85	55.15	4.791	7.169
2009	3.85	14.66	0.501	1.906
2010	47.67	46.13	6.197	5.997
2011	37.95	38.12	4.934	4.955
2012	*	*	*	*
2013	21.09	36.08	2.741	4.690
2014	20.85	27.52	2.710	3.577
2015 grazed	35.40	23.53	4.600	3.060
2015 mowed	47.56	47.26	6.180	6.140
2016 grazed	40.15	33.69	5.220	4.380
2016 mowed	51.38	52.46	6.680	6.820

Dry matter content calculated at 13% of fresh weight yield (Vylupek, 2010)

Table 5. Yield (fresh weight and dry weight t ha⁻¹) obtained from Coet-de-linge and Jonagold apple varieties in the mowed and grazed management treatments in 2015 and 2016 (mean)

Apple variety	Grass maintenance treatment	Fresh weight yield (t ha ⁻¹)	Dry weight yield (t ha ⁻¹)
Coet-de Linge	Mow	49.46	6.43
Coet-de Linge	Graze	37.76	4.91
Jonagold	Mow	49.85	6.48
Jonagold	Graze	28.62	3.72

To allow the input of sheep into the orchard and to determine if the sheep had any effect on apple scab during the growing season, fungicide applications for the control of apple scab were only carried out during early flowering. Coet-de-linge shows a better resistance to leaf scab than Jonagold. In August Coet-de-linge had 9.5% leaf scab compared to 71.6% for Jonagold. Coet-de-linge grazed plots recorded a slightly lower percentage of leaf scab in August (8.8%) than the mowed plots (10.2%), whereas the opposite was true for the Jonagold where the leaf scab in the grazed plots reached 72.8% compared to 70.5% in the mowed plots.

From post-harvest assessments, grazing had no effect on fruit scab incidences for cider which both had a mean of 0.25% fruit scab. Cider apples, such as Coet-de-linge, are grown solely to produce apples which are juiced to produce cider, so the appearance of the apple is not important. Cider Coet-de-linge fruit size increased with the presence of sheep with 10% more in the upper size band between of 60-80 mm compared to mowed plots.

Jonagold however is grown to supply the dual markets of fresh fruit and juicing. For the fresh market, skin finish is very important since top quality Grade 1 fruit should be pest and disease free. Jonagold from mowed and grazed plots had similar levels of fruit scab 45.5% and 44.0% respectively. However the percentage of unmarketable fruit scab differed with mowed plots having 6.25% and grazed plots 10.5%. Jonagold has typically a large fruit size of 70 mm and above. In this trial fruit size was generally smaller than normal with only 28.5% in mowed plots and 47.8% in grazed plots having a size greater than 70 mm. The apple packer/processor would consider levels of fruit scab and size grades of Jonagold apples when deciding which market route to follow. Considering the large levels of fruit scab and economics of sorting for the fresh market along with the low fruit size, all Jonagold produced in this trial would be likely to be sent to the juicing market resulting in a reduction in profit for the farmer.

Data from this trial confirms the need to maintain a full season pesticide spray programme especially for the control of apple scab with the Jonagold variety. This in turn would lead to greater labour input to manage the sheep during spray operations.

5.3 Effect of grazing orchards on sheep

Of the 20 sheep used in the trial only five spent their total time in the grass plots, the other fifteen spent between 4 and 21 days on grass with the rest of their time shared over the grazed cider and Jonagold plots. No adverse health effects were recorded for the sheep. Those sheep that spent 100% of their time on grass had an overall mean weight loss of 1 kg from entry to the site 12 May to 17 June 2015, while for the same period the other sheep had a mean weight gain of 3.83 kg, suggesting that there is an advantage to sheep of grazing in orchards. During the trial period sheep were seen to rest under the trees rather than in the open grass strips (Figure 2).



Figure 2. Sheep resting under the apple trees

5.4 Financial and labour impacts of grazing orchards

During May to June, when the sheep were active on the trial, the non-grazed plots were mowed on three occasions. The costs saving associated with managing sward heights with grazing is offset by additional labour costs required. Increased labour is required for daily management of the sheep, checking on numbers and health, checking grass levels and movement to fresh grass. Checking and movement of sheep within the orchard is more difficult and time consuming than in open pasture as they run through the trees. The presence of sheep in the orchard makes apple husbandry e.g. pesticide applications more difficult. Research will be required to determine if the sheep need to be removed from the orchard during such applications.

The trial data suggests that no serious bark stripping should occur as long as the grass levels in the orchard are maintained above a certain level, but failure to do so will result in major damage being caused in only a few hours. Financial losses can be expected through loss of production area (sheep stripped the lower branches of leaves and flowers up to a height of 1.14 m) and thus total yield harvested, from an orchard of dwarf or semi-dwarf apple trees where mixed-breed sheep are allowed to graze.

6 Lessons learnt

The main lesson from this trial is whilst there can be benefits from sheep grazing high pruned orchards, sheep can also damage young bush orchards where the canopy starts below 1.2 m

Four of the components of a grazed orchard system are i) the apple trees, ii) the spray programme, iii) the sheep, and iv) the manager. A successful grazed orchard system with sheep requires each of these components to be correct.

Apple tree structure: the growth of apple trees can be managed so that the final tree can vary in the height of the tree and the height of trunk with no branches. The traditional way of managing apples was to create a “standard” tree which has a 2 m tall trunk (with no side branches). A “half-standard” tree has a trunk of 1-2 m high, and a “bush” apple tree has a trunk of less than 1 m high (Robertson et al. 2012 page 47).

Spray programme: a full season pesticide spray programme especially for the control of apple scab needs to be maintained with the Jonagold variety. This requires greater labour input to manage the sheep during spray operations. Considering the large levels of fruit scab and economics of sorting for the fresh market along with the low fruit size, all Jonagold produced in this trial would be likely to be sent to the juicing market resulting in a reduction in profit for the farmer

Sheep breed: the behaviour of sheep breeds can vary substantially. Some lowland breeds are relatively sedentary whereas some upland breeds can behave like goats and are able to get on their two hind legs to reach browse. Selecting the appropriate sheep breed and stocking rate can be important to minimise tree damage.

Manager: a successful grazed orchard system requires a manager or a management arrangement that pays attention to the health of the apple trees and the daily monitoring of the sheep and the availability of grass. Successful management of such complex integrated systems can be labour and knowledge intensive.

7 Acknowledgements

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