MSc thesis

Introducing poultry in orchards to restore ecological relationships in agricultural production systems

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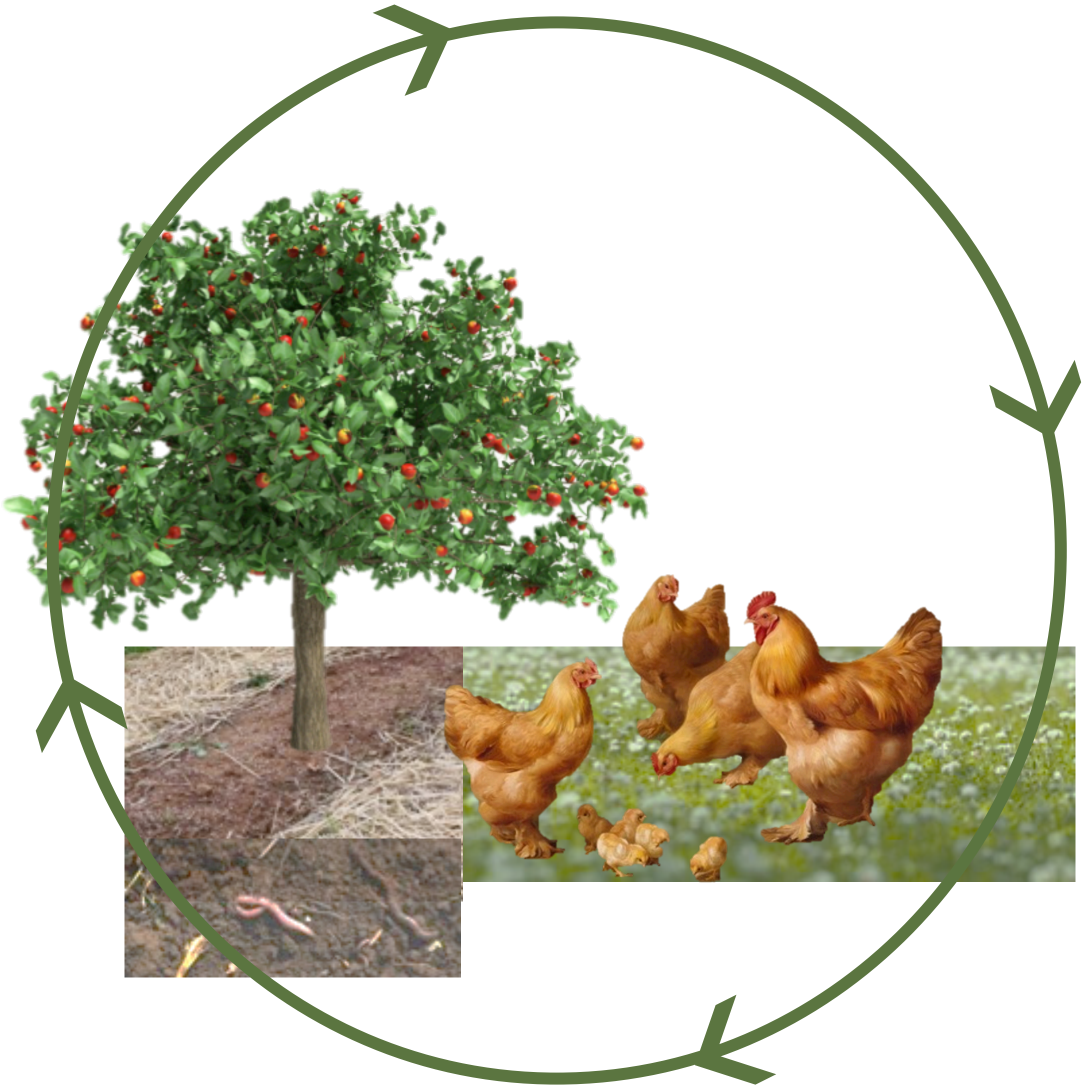

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Table of Contents

Summary

The main objective of this study was to identify the interrelationships between different aspects involved in a fundamentally new approach for rearing chickens. These aspects included integrating chickens in orchards, using mobile chicken coops, adjusting composition of diet, raising chicks by mother hens and using dual-purpose breeds. The most important finding of this study was that integrating poultry in orchards contributes to the re-establishment of natural living environments for chickens and enhances internal resource cycling within the farming system. Many of the potential benefits that result from introducing chickens orchards remain to be explored, but it can be concluded that this practice results in a lower input requirement for the farming system, while this increases diversity of outputs.

Integrating chickens in orchards was proven to contribute to natural behaviour patterns with 46% of the observed time spent on walking and foraging, which was substantially more compared to literature values of deep litter (23%) and battery cage systems (1%). This behavioural pattern was adopted at an early life-stage when chicks where reared by mother hens in the orchard (43%) compared to chicks reared without mother hens in a stable (6%).

It was estimated, based on manure sampling and using literature values of mineral nitrogen content in chicken manure, that mobile chicken coops that allow direct litter deposition on the sward results in a N fertilization of about 115 kg N ha^{-1} $year^{-1}$ at a density of 500 chickens ha^{-1}. Daily relocation of chicken coops is important to minimize N leaching when using chicken coops with direct manure deposition on the sward.

It was shown that, due to forage opportunities in the orchard, the supplied diet of chickens could be reduced in share of proteins, without affecting production levels. The supplied diet was composed of 50% concentrates and 50% spelt grains. A reduced share of proteins in the supplied diet decreases the environmental impact in the life cycle assessment for rearing chickens.

Regarding the use of dual-purpose breeds, net income was estimated to be 18% lower compared to using hybrid breeds in orchards. However, on farm-level, the decision towards adopting purebred dual-purpose breeds in orchards with on-farm propagation may be a more environmental friendly and ethically sound practice compared to using hybrid breeds in indoor stables.

Especially for small-scale extensive farming systems aiming to increase diversity of products the adoption of the proposed rearing system can be interesting. Further research could focus on reducing predation risk of chickens, which was considered the main bottleneck in adoption of the studied system.

1. Introduction

1.2. Restoring ecological relationships in farming systems

The industrial era led to increasingly specialized, simplified and technological innovation dependent farming systems. Labour efficiency, yield increase and rely on control management were the principle objectives of modern farming systems to meet food security needs, which were vigorously adopted to crop and animal production during the green revolution. The disconnection between the once interdependent plant and animal realms in agriculture resulted in efficient and highly productive farms, but it has been argued that this has led to less stable and resilient farming systems (Kirschenman, 2012; ten Napel et al., 2006). A high density of animals in artificial environments has resulted in animal welfare issues, thereby causing high impacts of improper management (Tilman et al., 2002) and large-scale monocropping practices in arable farming systems led to pest, weed and disease problems (ten Napel et al., 2006).

In response, alternative ways of practicing agriculture have been developed that aim to restore ecological relationships and to increase the use of natural resources in an on-farm closed cycle (Luttikholt, 2007). To achieve these objectives, understanding of ecological relationships and processes in farming systems is needed. Currently, farming systems are developing that reintegrate animal and plant production systems (Hermansen et al., 2004). One of such systems is the integration of poultry in orchards. Poultry in orchards contribute to the re-establishment of natural living environments for chickens and thereby potentially enhance symbiotic relationships between poultry and orchards (van Veluw, 1994). As a result, inputs to the system to control production can be minimized (ten Napel et al., 2006; Hermansen et al., 2004).

Over the last decades new rearing systems for chickens have been developed especially focussing on the improvement of animal welfare (Mollenhorst et al., 2005). However, since generally three different perspectives on animal welfare exist, there are debates about what rearing system supports animal welfare (Fraser, 2003). Animal welfare can be understood as (1) promoting good biological functioning in the sense of health, growth and reproduction, (2) reducing animal suffering and (3) supporting living natural lives (Fraser, 2003). Within the organic sector, the focus is mainly on supporting natural lives, thereby including the possibility to perform natural behaviours, feed adapted to the animal's physiology and a natural living environment (Lund, 2006). This perspective can be understood from the underlying philosophy of organic agriculture (Luttikholt, 2007). The practice of introducing chickens in orchards converges with this perspective, because it has the potential to support natural environments for chickens.

1.3. Potential benefits of poultry in orchard systems

However, the practice of introducing chickens in orchards is a relatively new concept in the Netherlands and may provide solutions to challenges current practices face, especially those following organic standards. Therefore, this study focused on the main practical consequences and opportunities for the design of the integration of poultry in orchards, including housing conditions, feed provisioning, introduction of maternal care and use of dual-purpose breeds. These aspects were integrated on a farm and analysed on their performance regarding fertilization, feed use efficiency, animal behaviour and output production. Thereafter, these results were evaluated using existing knowledge on current chicken rearing systems. As an outcome of this study, the main interrelationships between the different aspects involved that shape the system of poultry within orchards were identified to further develop this practice.

1.3.1. Housing

In the Netherlands, current chicken housing in regular and organic rearing systems mainly comprises static buildings. In organic livestock production systems, a shift towards a more natural living habitat is aimed for (Lund, 2006) and an outdoor area of 4 m^2 per chicken must be provided (SKAL, 2015). However, several studies have identified that chickens are not spreading homogeneously throughout the outdoor area in an open area like grasslands without trees and mainly concentrate close to the buildings (Rivera-Ferre et al., 2006). This often results in high vegetation pressure and therefore high nutrient leaching potential, especially nitrogen, in the areas close to the buildings (Rivera-Ferre et al., 2006). In orchards, mobile housing systems could be used, which is a relatively new concept in the Netherlands (Antonissen & Lantinga, unpublished).

It was found in earlier studies that mobile housing supports the use of the outdoor area and leads to a reduction in vegetation damage and a more even distribution of manure compared to static housing systems, thereby resulting in a lower nutrient leaching potential (Antonissen & Lantinga, unpublished). Nitrogen loading of broilers from 49 days of age until 87 days of age in mobile chicken coops was estimated to be 36 kg ha^{-1} on the pasture at a density of about 380 chickens ha^{-1}, suggesting a chicken coop could be left about 38 days without exceeding legislative nitrogen concentrations in the groundwater (Antonissen & Lantinga, unpublished).

However, in the present study, mobile chicken coops were used that allowed chicken litter deposition of laying hens during the night on the pasture directly below the chicken coop. Using chicken coops that allow direct litter deposition reduces labour demand for collecting manure and cleaning chicken coops and might improve air quality in the chicken coop because of lower ammonia concentrations (Bestman et al., 2011). Furthermore, these chicken coops are relatively light and can therefore be easily relocated. Yet, this type of mobile housing may increase the concentration of nitrogen deposited directly under the coop. Relocation of chicken coops following from this management should, therefore, probably take place more regularly for spreading manure homogeneously without exceeding groundwater nitrogen concentrations as compared to mobile chicken coops that collect manure of chickens during the night (Antonissen & Lantinga, unpublished). Calculating the manure load of deposited litter directly on the pasture using this type of chicken coops provides insight in how often relocation of the chicken coops should take place.

On the studied farm, three chicken coops were used in the pasture for housing chickens, which were standing next to each other in three different rows. In order to spread manure homogeneously, chickens must distribute evenly over the three chicken coops. Therefore, assessing the distribution of chickens over a period of time in the chicken coops may give insight in whether the current practice supports homogeneous distribution of manure on the pasture.

1.3.2. Feed

In regular chicken rearing systems diets include nearly 100% concentrates and within such systems chickens are supplied wheat grains only to stimulate forage behaviour (Bestman et al., 2011). However, because of nutritious foraging opportunities already present in the orchard, chickens may gain a larger share of proteins for their dietary needs by feeding on invertebrates (e.g. insects, larvae and earthworms) and vegetation compared to regular chicken rearing systems (Walker & Gordon, 2003; Hermansen et al., 2004).

This might be a solution for the EU legislative implementation end 2017 when organic chicken diets should consist of 100% organic ingredients (van Krimpen et al, 2015a). Currently, 5% of chicken feed comes from conventional origin because otherwise the essential amino acid methionine, being the first limiting amino acid (van Krimpen et al., 2015b), is lacking in the diet of organic chickens (van Krimpen et al., 2015a). A reduced methionine content in chickens' diets may result in lower laying performance (van Krimpen et al., 2015b). However, it has been reported that foraging on invertebrates may contribute to a large extent to the methionine requirements (Wagenaar & Visser, 2006) and integrating chickens in an orchard may, therefore, resolve this issue.

In the study of Hughes & Dun (1983), it was estimated that the amount of supplied feed in the diet of laying hens could be reduced by 33% when chickens were integrated on a pasture. In a study conducted by Antonissen & Lantinga (unpublished), restricting the supplied diet of broilers to 70% of ad libitum amounts with a diet consisting of 60% concentrates and 40% wheat led to a herbage intake from the pasture comprising 28% of the total feed intake. Therefore, integrating chickens in orchards provides an effective way for reducing feed costs, which contribute to a large extent to the variable costs of chicken rearing (Walker & Gordon, 2003). Besides, especially the production of concentrates makes up a substantial part of the environmental pollution in the life cycle analysis of poultry rearing (Nguyen et al., 2010).

For laying hens, however, to date there has been no study conducted on reducing the share of proteins in their diet when integrating chickens in orchards and the subsequent effect on laying performance. This study provided the first approach to assess laying performance of chickens in orchards with a supplied diet of 50% concentrates and 50% spelt grains.

One of the recurrent operations in the orchard on the studied farm is tree strip cultivation, a procedure for uprooting weeds and aerating the soil around the fruit trees using a Tournasol. As a result, chickens may require even less from the provided feed and feed conversion ratio, expressed as kg supplied feed/kg egg, can be reduced. Since earthworms contribute to a major proportion of invertebrate biomass in the soil and are common natural feed sources for chickens (Edwards, 2004), assessing dynamics of earthworms during presence of chickens can be a reliable factor to assess the potential of natural forage opportunities in orchards.

1.3.3. Animal behaviour

The integration of chickens in orchards is assumed to provide a more natural living condition for chickens, but this assumption has thus far not been tested according to animal behaviour patterns. Earlier studies have found that increased feather pecking incidence, an indicator for the association with stress (El-Lethey et al., 2000), was observed in battery cage systems compared to deep litter stables, caused by a lack of substrate for foraging and dustbathing (Mollenhorst et al., 2005; Blokhuis, 1986). Foraging and comforting behaviours that require more space, like dustbathing, were significantly less identified in battery cage systems compared to deep litter stables (Mollenhorst et al., 2005). On top of that, smaller flocks of chickens that are kept in an outdoor run introduced at a young age together with cockerels were found to express even lower feather pecking damage (Bestman & Wagenaar, 2003). A higher percentage of cover in a chicken run was found to increase outdoor run usage (Bestman et al., 2014), resulting in a high potential for improving poultry welfare in orchard systems, where fruit trees are abundant. Scoring animal behaviour can be an appropriate tool to assess whether a more natural behaviour pattern is actually observed. As a baseline, the behaviour pattern of the common ancestor of the domestic chicken red junglefowl (*Gallus gallu*s L.) can be compared to the observed patterns in the domestic chicken flock (Dawkins, 1989).

1.3.4. Maternal care

Another practice that supports natural living conditions for chickens is the introduction of maternal care. Influences of maternal care on chicks have been intensively studied and results indicate that the presence of mother hens during rearing of chicks has many benefits relating to the welfare of chicks (Bestman & Wagenaar, 2003; Rodenburg et al., 2009ab; Edgar et al., 2016). Besides, part of being a hen includes providing maternal care for chicks and withholding hens from being a parent can be seen as reducing animal welfare (Edgar et al., 2016).

Considering the welfare of chicks, it was found that the presence of a mother hen during rearing improves foraging and social behaviour (Rodenburg et al., 2009ab). Also, feather pecking and fearfulness of chicks were both reduced. In the study of Riber et al. (2007) it was found that chicks that were raised by a foster-mother hen performed more ground pecking, used perches more at a younger age and had a lower mortality compared to chicks grown up without a foster-mother hen. Conclusively, as Rodenburg et al. (2009ab) summarizes, positive effects of brooding should be translated for application in commercial systems. Their view is supported by Edgar et al. (2016), though it has been suggested that the positive cues should be *artificially* integrated since the biological way of rearing chicks is commercially not feasible. However, to date there has been no research done on rearing chicks by mother hens following the biological approach of maternal care in an orchard system. From a commercial perspective, this could be a more interesting model for rearing chicks by mother hens.

1.3.5. Dual-purpose breeds

Because of the increasing demand for animal welfare in extensive production systems, new traits continue to enter the selection matrix. Not only breeding for specific traits, but also different selection methods for breeding are used. For instance, group selection for a lower mortality rate has successfully shown to reduce propensity to develop feather pecking (Rodenburg et al., 2009ab). However, most developments aim to genetically improve the typical 4-line cross hybrid chickens. A more fundamental approach to improve animal welfare on the genetic level can be to reverse the differentiation of hybrids by developing purebred dual-purpose breeds (Damme & Ristic, 2003).

Dual-purpose breeds may be a solution for the redundancy of male chicks in hybrid dependent egg production systems (Nauta et al., 2003; Ellendorf et al., 2003) and for the fast-growing broilers in the meat industry with related physiological issues (Bessei, 2006). Currently, Stichting Biologische Fokkerij is developing a purebred dual-purpose poultry breed meant for both egg laying and meat production (Nauta et al., 2011) in response to the dependency of organic poultry systems on the conventional breeding supply. As Nauta et al. (2003, p.5) mentioned: *"Interest in breeding has increased because organic agriculture is expanding and as yet too little attention has been paid to the development of specific organic breeding programmes and associated legislation."* However, there is little knowledge on the practical implementation of dual-purpose breeds in production systems and their financial consequences. Within the report of Leenstra et al. (2014) a comparison on egg production with model calculations was made between conventional and organic production systems with hybrid layer hens, heavy layer hens and dual-purpose breeds. It was shown that dual-purpose breeds have higher feed costs for similar egg and meat production and the ecological food print is therefore larger. Yet, integration of chickens in orchards may provide ways to reduce the ecological food print that could, on a farm level, make rearing dual-purpose chickens more attractive, thereby also contributing to a more ethical responsive way to rear chickens.

1.4. Research objectives, study location and hypotheses

As mentioned above, integrating chickens in orchards using mobile chicken coops can be an interesting approach to enhance on-farm resource cycling, while at the same time contributing to a more natural living environment for chickens. On top of that, novel approaches for rearing chickens in an orchard can be implemented that improve animal welfare and contribute to a more ethical responsible way of rearing chickens, like on-farm propagation using the biological way of raising chicks by mother hens and use of dual-purpose breeds instead of hybrid breeds. These practices are more difficult to implement in regular chicken rearing systems, because of space requirements and financial aspects.

Combining all above-mentioned aspects together, i.e. integrating chickens in orchards, adjusting composition of diet, using mobile chicken coops, raising chicks by mother hens and using dual-purpose breeds, can be considered as a fundamental new approach for rearing chickens. To date there has been no study carried out on how these aspects are interrelated and what the main bottlenecks are for adopting this practice. Therefore, in this study *the main objective was to identify the interrelationships between the different aspects involved in this fundamental new approach for rearing chickens and determine the main bottlenecks involved.*

This research project was carried out on a farm that has been practicing rearing of poultry in an orchard for several years. Urban farm 'Fruittuin van West', located in Amsterdam Nieuw-West, comprises 6 hectares with over 20 fruit varieties and includes 250 Lohman Brown hybrid laying hens. The chickens are housed in three mobile chicken coops measuring 8 m^2 each that are relocated daily through the pasture rows in the orchard. The chicken coops are only meant for sleeping and feed and water is provided ad libitum in the orchard. Furthermore, the farmer feeds the chickens with a diet composed of 50% concentrates (laying pellets) and 50% spelt grains. Tree strip cultivation, as explained before, is a recurrent practice on the farm.

For the present study the following sub-objectives have been identified:

1. To estimate N fertilization in the swards between the fruit tree rows by chicken litter deposition in mobile chicken coops that allow direct litter deposition on the pasture with distribution of chickens among the mobile coops as a variable factor.
2. To study laying performance, indicated by laying percentage and egg weight, of laying hens in the orchard with a supplied diet reduced in protein share, i.e. consisting of 50% concentrates and 50% spelt grains. In line with this, to assess dynamics in populations of commonly foraged invertebrates, especially earthworms, and their response to tree strip cultivation.
3. To determine whether integration of poultry in orchards leads to more natural behaviour patterns compared to regular rearing systems by using the baseline behaviour pattern of the red junglefowl (*Gallus gallus* L.).
4. To design a system for commercial implementation of rearing chicks by mother hens in an orchard and to determine the contribution of maternal care for the adoption of natural behaviour patterns by chicks.
5. To determine financial consequences for commercial integration of dual-purpose breeds in an orchard with on-farm propagation and comparing this to the use of hybrid breeds.

These objectives have resulted in the following hypotheses:

1. Using mobile chicken coops with direct litter deposition results in a need for more frequent relocation of the coops to prevent nitrogen leaching compared to mobile coops that collect manure of chickens during the night. Chickens were hypothesized to be evenly distributed among the chicken coops.
2. Feed conversion ratio of the supplied feed to laying hens, expressed as kg supplied feed/kg egg, was hypothesized to be lower in the 'Fruittuin van West' farm as a result of foraging on naturally available resources. Due to foraging and tree strip cultivation, abundance of earthworms in the soil within the fruit tree rows was hypothesized to be lower when chickens were present.
3. Chickens in the production system of 'Fruittuin van West' were hypothesized to exhibit a more similar natural behaviour pattern to the common ancestor of the domestic chicken red junglefowl (*Gallus gallus* L.) (Dawkins, 1989) compared to chickens in regular housing systems (i.e. battery cages and deep litter stables, Mollenhorst et al., 2005).
4. Chicks reared by mother hens in an orchard were hypothesized to sooner adopt a similar behaviour pattern to adult chickens in the orchard compared to chicks reared without a mother hen in the stable.
5. Regarding dual-purpose breeds, it was hypothesized that it would be just as profitable to rear dual-purpose breeds in orchards with on-farm propagation of the flock due to lower costs compared to rearing hybrid breeds in orchards.

2. Methods

2.1. Housing

For this study, three chicken coops (8 m^2 each) housing 250 birds in total were allocated to three separate rows next to each other in a fenced-off area of 0.5 ha on the farm (Figure 1). The chicken coops were moved 4 m (i.e. one coop's length) per day through the rows until the chicken coops had covered the whole area (Figure 2). This would take about 8 weeks and, thereafter, all chickens were moved to another part of the orchard that was fenced-off.

Figure 1: Chicken coop in the orchard at Fruittuin van West

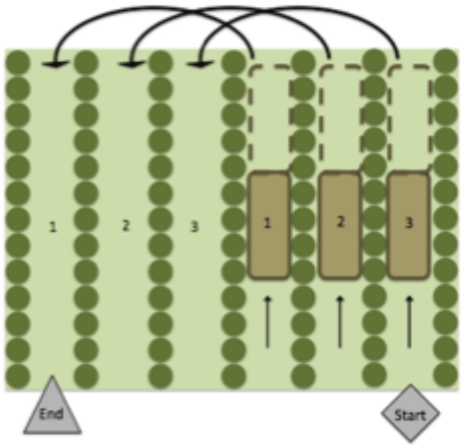

Figure 2: Schematic representation of relocation of mobile coops indicating starting position in the fenced-off location ('start') and end position before allocating chickens to the next fenced-off location ('end'). In reality, there are more rows between the start and end position. Chicken coops are indicated by the brown rectangles representing their number according to the observations. Every day the chicken coops are relocated 4 meters (i.e. one coop's length) (dashed lines) and at the end of a row chicken coops are relocated to new rows according to the figure.

For determination of manure distribution within one fenced-off area, all chickens were counted during five consecutive nights in their chicken coops. When chickens are on the perch at night, excreta will drop directly on the pasture, thereby contributing to fertilization. The fresh excreta was collected and weighed the next morning from each of the three chicken coops. The amount of manure was divided over the number of chickens in the concerning coop to get to an average of amount of excreta per chicken dropped on the pasture per night. This number was multiplied by the average total number of chickens per coop. Since every coop was replaced one coop's length (i.e. 4 m) every day through the rows in between the fruit trees, the chicken coop that was always closest to the final position in the particular area was denoted as 'first' and the chicken coop that followed was denoted as 'second'. The chicken coop that was always closest to the starting position was denoted as 'third' (Figure 2). Mineral nitrogen content of chicken manure was retrieved from literature (Smith et al., 2000) and was used to calculate N fertilization per kg of chicken manure deposited below the chicken coops and on the pasture. The total amount of manure below each chicken coop was multiplied by the number of chickens that slept in the corresponding coop. This led to an average N fertilization of chicken manure below each coop per night. Total chicken coop area was 24 m^2 and N fertilization was expressed as kg N ha^{-1} $year^{-1}$. Since chickens excrete on average 115 grams of manure per day (Smith et al., 2000), the amount of manure that was deposited below the chicken coop per chicken was subtracted from the 115 grams, resulting in total manure excreted on the pasture during the day. The amount excreted during the day was multiplied by the mineral N content in the chicken manure and by the number of chickens ha^{-1} (i.e. 500 ha^{-1}). This was again multiplied by the number of days chickens were present in the particular location (i.e. 56 days). Adding up the N fertilization of chicken manure below the chicken coop during the night by the N fertilization on the pasture during the day

2.2. Feed

Feed conversion ratio, expressed as kg supplied feed/kg egg, was measured over a period of 24h. When the sun sets, chickens move to their perches in the chicken coops and quit feeding. After sun set, therefore, all 10 available feeding boxes were filled with 50% grains and 50% concentrates and subsequently weighed. Next day, eggs were collected, counted and a subsample of (n=10) eggs was weighed on a fine-scale balance and replicated 6 times, so N_{tot}=60 eggs. Individual egg weight was back calculated for the whole batch of eggs. All feeding boxes were weighed 24h after the initial weight measurement and total kg of feed consumed could be calculated. This was divided over the total weight of eggs to get the feed conversion. Measurements were carried out once a week over a period of 10 weeks, from February until May.

During three of ten feed conversion measurements, tree strip cultivation was practiced to detect whether feed conversion ratio would decrease. Tree strip cultivation was practiced on the 1st of March, 6 weeks later, on the 14th of April and 11 days later, on the 25th of April. For this, all rows in the area where chickens were present were cultivated over a period of about 2 hours using a Tournasol that mixes the top 2-3 cm of the soil from the tree up to about 25 cm in the sward. This attracts chickens to forage on exposed macrofauna (Figure 3). Feed conversion ratio was measured during these days, using the similar procedure as the other feed conversion ratio measurements. The feed conversion ratios after tree strip cultivation on the three separate dates were compared to the average feed conversion ratios measured without practicing tree strip cultivation.

Figure 3: Attraction of chickens after tree strip cultivation

Laying percentage was also measured to compare laying performance with other Dutch organic chicken rearing systems (Leenstra et al., 2014). For this, all chickens were counted in their chicken coops for a total of 8 days and the number of eggs collected during the following day was divided over the number of chickens counted.

For studying macrofaunal dynamics during foraging of chickens and as a response to tree strip cultivation (Teeuwen & Schramm, Appendix 2), the number of earthworms was used as an indicator for soil macrofauna, because their large size makes them one of the major contributors to invertebrate biomass in soils (Edwards, 2004). Earthworms were measured in the location where chickens were present and where chickens had not been present. Both locations were subjected to tree strip cultivation, as mentioned above. However, in the location where chickens were not present, only 5 rows were cultivated. Six soil samples were taken the day before tree strip cultivation, during the day when cultivation was practiced and nine days after cultivation. Another six soil samples were taken 16 days after cultivation, but only in the field where chickens were present at the time of measurements due to logistics at the farm. The fields where the measurements were taken for harvesting biomass included a location where the chickens were present at the time of measurements and a location where chickens had not foraged before (see section 2.1.). At each sampling site, a volume of 20x20x20 centimetres of soil was taken by digging vertically into the ground with a spade. Earthworms from each sample were sorted and counted by hand. Due to the large variability in earthworm size, weight of the total number of worms was determined per sampling site prior to tree strip cultivation. Average weight per worm was calculated by dividing weight per sample (g) with total number of worms per sample.

2.3. Animal behaviour

Analysing chicken behaviour patterns was performed following the instantaneous scan sampling method (Martin & Bateson, 2007) according to the study of Mollenhorst et al. (2005) with which the resulting behaviour patterns of the hybrid laying hens in Fruittuin van West were compared. For this, one person observed the chicken flock in three sessions of 30 min. each during one day for a total of 6 days. Cockerels were not included in the analysis. Chicks from the dual-purpose breed grown up with and without mother hens (see section 2.4.) were analysed at three weeks of age for four days following the same instantaneous scan sampling method.

The area where the chickens were present was subdivided into four functional areas, i.e. the area around the eating and drinking facilities, the area close to the chicken coops and two distinct forage areas where chickens were present at that particular time. The sequence of observing in the four functional areas was randomly depicted each day of performing observations. Each session started with the observer to walk for 5 minutes to the functional area following an adaptation period of another 5 minutes. Next, all individuals present in an observation plot were observed every minute and behaviours were scored according to the ethogram (Table 1).

Similar to the analysis of Mollenhorst et al. (2005), scan sampling data of all four functional areas within one observation day were summed into a total number of individuals performing each of nine behaviours. Rather than summarizing per session (Mollenhorst et al., 2005), the scan sampling data of the Fruittuin van West were summarized per day for all three sessions, because of the relatively heterogeneous behaviours of outdoor foraging chickens throughout the day (Bestman et al., 2011). Subsequently, for each observation day, the percentage of individuals performing each of nine behaviours was calculated.

Table 1: Ethogram of instantaneous scan sampling, adapted from Mollenhorst et al (2005)

Behaviour	Description
Stand	Standing idle, no body contact to floor
Sit	Sitting idle, body on floor
Walk	Locomotion from one place to another
Forage	Scraping over floor with feet, pecking on floor
Eat	Eating from feeding boxes
Groom	Cleaning with beak or feet, feather ruffling, preening
Drink	Drinking water from water nipples
Dust-/sunbath	Laying down in substrate and making fluttering movements
Rest	Laying down or sitting on perch with closed eyes

2.4. Maternal care

The design for raising chicks by mother hens was adapted from the current practice of rearing hybrid laying chickens in the Fruittuin van West. For this, one of the reserve chicken coops on the farm was reconstructed and allocated to a fenced-off site in the orchard. The chicken coop was meant to house mother hens for developing broodiness. Seven hens were introduced from the Orpington breed and were obtained from different hobby breeders. Similar to the current practice, feed and water was supplied in the orchard and hens were allowed to forage in the orchard during the day. Multiple nests with imitation eggs were provided for the hens in the chicken coop (Figure 4). Once a hen would develop broodiness, the nest including the hen was relocated to another compartment within the chicken coop such to create an undisturbed environment for the hen to brood the imitation eggs.

Figure 4: Adapted chicken coop with laying nests (blue boxes) including imitation eggs provided to stimulate broodiness of hens

Once multiple hens had developed broodiness, an incubator was installed with a capacity for hatching a total of 500 eggs. The fertilized eggs were from the purebred dual-purpose breed of breeder Wytze Nauta (Stichting Biologische Fokkerij), called 'Vredelinger'. After 18 days of incubation, 3 days before hatching, eggs were sorted out that did not contain an embryo. Also, during this time, 15 fertile eggs were put under each broody hen and replaced the imitation eggs. Once the chicks hatched under the mother hen, the nest including hen and chicks was placed in a 1m^3 wooden box with mulching material as ground cover and providing ad libitum starter's feed for chicks and water. The mother hens and chicks were given access to a fenced-off outdoor area of 15 m^2 during the day (Figure 5). The eggs that did not hatch under the mother hens at day 1 were exchanged for 1-day-old chicks from the incubator until every mother hen had a total of 15 chicks. After three weeks, mother hens with their chicks were reintroduced in the orchard at the location where the mother hens were housed.

Figure 5: Wooden boxes in a fenced-off area on the farm for keeping mothers and their chicks

The remaining eggs were hatched in the incubator and 90 chicks were put in three wooden boxes measuring 1 m^3 each, similar to the boxes the mother hens and chicks were allocated to. Conventional heat lamps provided a comfortable temperature and food and water was provided ad libitum. After two weeks, chicks were allowed to forage in the entire stable measuring 30 m^2. After six weeks of age, chicks were moved to the orchard.

Thus, chicks raised by mother hens were reared in the orchard and chicks raised without mother hens were reared in the stable. Differences in hatching rate, feed consumption, growth rate, behaviour and mortality measured between the two treatments were neither attributed to presence/absence of mother hens nor outdoor/indoor conditions, but attributed to the combined factors. The comparison as such was chosen because in the study of Edgar et al. (2016) it was argued that maternal care could not be introduced in regular systems due to large space requirements that the concerning rearing systems cannot offer. However, an orchard provides more space for raising chicks by mother hens. Yet, chicks raised without a mother cannot be raised in the orchard due to temperature stress.

Measurements included comparisons of hatchability of chicks in the incubator and by mother hens. During the experiment losses of chicks to predators or due to other causes were recorded. Furthermore, growth rate of chicks was measured by weighing a total of n=6 chicks at the age of 1 week, 2, 3, 4 and 12 weeks. An equal number of cockerels (n=3) and hens (n=3) were taken for each measurement, but during the first weeks of age cockerels and hens could not yet be separated.

Feed consumption was measured from 2 to 3.5 weeks of age for every half a week. For this, feed storage bags were separated for chicks with mother hens and chicks without mother hens. Feed troughs were equally filled up before every measurement and the difference in weight of feed storage bags before and after filling feeding boxes were an indicator for consumed feed. The difference in weight of feed storage bags before filling up feed troughs and after filling up feed troughs was divided over the chicks. During the course of these measurements, feed troughs of the chicks raised by mother hens were adapted for more efficient feeding by chicks such that spillage was reduced and the mother hens and other chickens had no access to the feed boxes. Lastly, as mentioned earlier, at three weeks of age behaviour assessment was performed (see section 2.3.).

2.5. Dual purpose breeds

Currently, in the Fruittuin van West hybrid laying hens are reared. Within the present study an analysis was made whether the introduction of dual-purpose breeds in an orchard would be as profitable as hybrid chickens. For this, a financial comparison of dual-purpose chickens (Figure 6) and hybrid laying and meat chickens was made.

Figure 6: Picture of hens and cockerels of the dual-purpose breed 'Vredelinger'

Since there was no data available on feed consumption of dual-purpose laying hens in orchards, feed consumption of dual-purpose laying hens was assumed to be the same as for the hybrid chickens, which was acquired in this study (i.e. 120 g feed day^{-1} hen^{-1}). Laying percentage for hybrid laying hens was set at 84%, as measured in this study, and for dual-purpose breeds 65%, as retrieved from breeder Wytze Nauta (personal communication, April 5, 2016). After their laying period, hens were slaughtered. Hybrid laying hens were modelled to weigh about 1.2 kg hen^{-1} (Wil Sturkenboom, personal communication, October 21, 2016) and dual-purpose hens were modelled to weight about 1.5 kg hen^{-1} (Wytze Nauta, personal communication, April 5, 2016).

Parameters for hybrid broilers on dressed weight at slaughter age (1.5 kg at 81 days) and total feed consumption (6.3 kg broiler^{-1}) were taken from literature (Castellini et al., 2010; Pedersen et al., 2003), following the standards of organic broiler production (SKAL, 2015). Parameters for dual-purpose cockerels on dressed weight at slaughter age (1.5 kg at 140 days) and total feed consumption (7.0 kg cockerel^{-1}) were acquired from breeder Wytze Nauta (personal communication, April 5, 2016).

Furthermore, the practice of brooding chicks was taken into the calculation for the system with dual-purpose breeds and was compared to the rearing system using 1-day-old hybrid broiler chicks and hybrid laying chickens of 20 weeks of age. A production cycle takes 365 days, in which a total of 500 chickens were simulated for both the dual-purpose breed and for hybrid laying chickens and broilers. This number of chickens was based on the demand of the farmer to increase his flock size by two-fold for selling more eggs to the customers. During the production cycle, mortality, expressed as the share of the total flock, was included in the calculations. Mortality was based on the recorded data on the decrease in number of chickens in the orchard over a period of 17 weeks. The mortality for dual-purpose chicks reared in the orchard by mother hens was based on the data of the experiments.

Regarding propagation of the flock of the dual-purpose breed, the replacement rate of laying hens was set at 33% every year. So, laying hens of the dual-purpose breed are slaughtered at the age of 3 years. Thereafter, they are sold for meat. Because of a tougher meat quality, prices were assumed to be lower

(€10,- kg^{-1} for meat of hens versus €12,- kg^{-1} for meat of cockerels). A consequence of propagation is that 50% of the new stock consists of cockerels. Since the total flock was set at 500 chickens, every year 125 hens and 125 cockerels were added to the flock and during the same year 125 laying hens and 125 cockerels were slaughtered. The same numbers of hybrid laying hens and hybrid broilers per year (i.e. 375 and 125 respectively) were used in the model to compare with dual-purpose breeds.

For raising 250 chicks with 15 chicks per mother hen, 17 mother hens are needed for propagation of the flock. Price per mother hen was determined by multiplying the number of eggs the hen would not lay during the time of broodiness and raising chicks, in total 50 days per mother hen, with the price per egg. During the broody period (i.e. 21 days), a hen consumes a limited amount of feed only. Therefore, feed intake was assumed to be 42% (i.e. 21 days divided by 50 days) lower compared to what a laying hen would consume when not broody.

For feeding the chicks of the dual-purpose breed, it was assumed that chicks would feed on starter's feed for two weeks before converting to a diet of 50% concentrates and 50% grain. Usually this period is much longer, until 6 months for regular indoor systems (Bestman et al., 2011), but it was assumed that the orchard provides sufficient proteins to account for the deficiency. For hybrid broiler chicks this period was set at four weeks, after which they are relocated from the stable to the orchard where they start on the diet of 50% concentrates and 50% grains.

2.6. Statistical analyses

The number of samples required for statistical significance between treatments was calculated according to the formula $n_{A,B} = \sigma_{A,B}^2 * ((z_\alpha+z_\beta)^2 / \Delta^2)$ with α (significance level) being 0.05 and β (statistical power) being 0.8. However, since most measurements were conducted for the first time and no literature could provide an estimate for σ (standard deviation of the population mean) and expected Δ (difference between treatments), number of observations was kept within practical limits (mostly n=6 per treatment).

Data was analysed using SPSS version 22.0. Data cases were split to compare measurements in the different areas on the farm (i.e. the location where chickens were present at the time of measurements, the location where chickens were present 9 months ago and the location where chickens had not been present). Prior to ANOVA using a GLM procedure, data were first examined for normal distribution by Levene's test and Q-Q plots. Data were presented as averages and their standard deviations (SD).

3. Results

3.1. Housing

The number of chickens that were counted in each mobile chicken coop during (n=5) nights was consistently lower in the first chicken coop (P<0.05; 38, SD = 18) and higher in the third coop (P<0.05; 137, SD = 23) with the second coop in between (P<0.05; 92, SD = 25) (Figure 7). The first chicken coop was always closest to the end position in the fenced-off location and the third chicken coop was always closest to the starting position (Figure 2).

The average amount of excreta added to the soil during the night was 47.5 gram per chicken (SD=3.15), which was calculated to be the equivalent of 0.029 g N assuming 16 g N kg^{-1} excreta (Smith et al., 2000). Based on the area of the chicken coop (24 m^2) and multiplied by the average number of chickens per chicken coop this was calculated to be the equivalent of about 37, 87, and 130 kg N ha^{-1} for the first, second and third chicken coop respectively.

The total amount of fresh excreta a chicken drops on the pasture per day was estimated to be 115 g (Smith et al., 2000). The amount of manure supplied to the pasture per chicken per day is therefore 67.5 g. Because the chickens in the orchard comprised an estimated density of 500 chickens ha^{-1} during 8 weeks per year per location, the total amount of manure supplied to the soil was calculated to be about 2 Mg. This was calculated to be the equivalent of 30 kg N ha^{-1} $year^{-1}$.

Adding up this number with the average manure supplied during the night (85 kg N ha^{-1} $year^{-1}$), the total manure addition of chickens with a density of 500 chickens ha^{-1} was calculated to be 115 kg N ha^{-1} $year^{-1}$ and (Table 2).

When calculating the nitrogen excretion based on feed intake and N retention in eggs (Smith et al., 2000), fertilization rate was estimated to be about 135 kg N ha^{-1} $year^{-1}$ (Table 3), which is 20 kg N ha^{-1} $year^{-1}$ more compared to the calculation based on manure collection (Table 2).

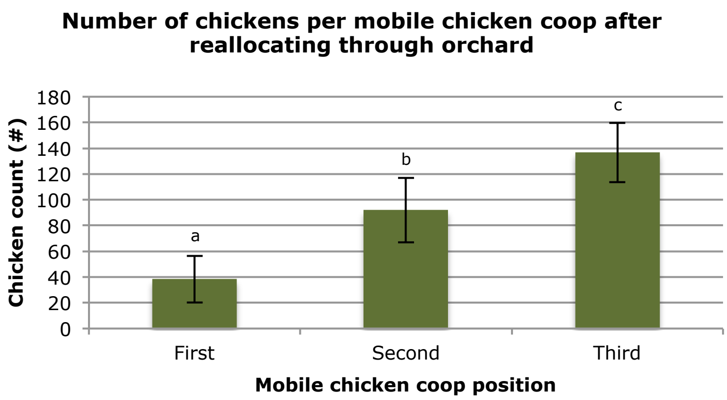

Figure 7: Average distribution of chickens in the three chicken coops counted at night when chickens were on the perch. 'First', 'second' and 'third' refers to the position of the coop in the location where chickens were allocated to (Figure 2). Different letters indicate statistical significance at the 0.05 level.

Table 2: Calculations of manure and nitrogen distribution under the chicken coops and within the fenced-off location where chickens were allocated

	Night (under coop)	Day (whole pasture)	kg N ha^{-1} $year^{-1}$
# chickens	267	500	
Manure amount (g/chicken/day)	47.5	67.5	
g N/kg manure (Smith et al., 2000)	16	16	
Area (m2)	24	10000	
kg N/ha	85	30	115

Table 3: Calculations of nitrogen excretion based on feed intake and egg production (Smith et al., (2000)

	Amount	Unit
N intake (feed)	1100	g N $bird^{-1}$ $year^{-1}$
N retention (egg)	311	g N $bird^{-1}$ $year^{-1}$
N excretion	788	g N $bird^{-1}$ $year^{-1}$
Average N fertilization	135	kg N ha^{-1} $year^{-1}$
Difference (Table 2)	20	kg N ha^{-1} $year^{-1}$

3.2. Feed

The average feed conversion ratio of laying hens in the Fruittuin van West, expressed as kg supplied feed kg egg^{-1}, was 2.3 (SD = 0.4). This measurement was based on N=10 measurements with a density of 500 laying hens ha^{-1} over a period of 17 weeks from February until May 2016. The number of eggs collected during the N=10 measurements was divided over the number of chickens present and laying percentage was subsequently calculated to be 84% (SD = 5) (Table 4). Furthermore, average individual egg weight was measured to be 64 g (SD = 1) (appendix 3).

Values obtained from the measurements in Fruittuin van West were compared to values of Dutch organic farming systems from the study of Leenstra et al. (2014) on feed conversion ratio (2.4 kg feed kg egg^{-1}) and laying percentage (85%) during the period from 2008 until 2012.

Table 4: Feed conversion ratio and laying percentage of laying hens in Fruittuin van West.

	Feed conversion ratio (kg feed kg egg^{-1})	Laying %
Fruittuin van West	2.3 (SD = 0.4)	84 (SD = 5)
Average values of Dutch organic farms 2008-2012 (Leenstra et al., 2014)	2.4 (SD = 0.1)	85 (SD = 3)

The average feed conversion ratio after tree strip cultivation was 2.0 kg egg/kg feed (SD = 0.4) and the average of the measurements without tree strip cultivation was 2.4 kg egg/kg feed (SD = 0.3). However, the decrease in feed conversion ratio after tree strip cultivation was not significant. After analysis of the three tree strip cultivation events it became evident that the feed conversion ratio seemed to increase after every subsequent cultivation event, from 1.7 kg egg/kg feed (first measurement) to 1.9 kg egg/kg feed (second measurement; after 6 weeks) to 2.5 kg egg/kg feed (third measurement; 8 weeks after the first measurement) (Figure 10).

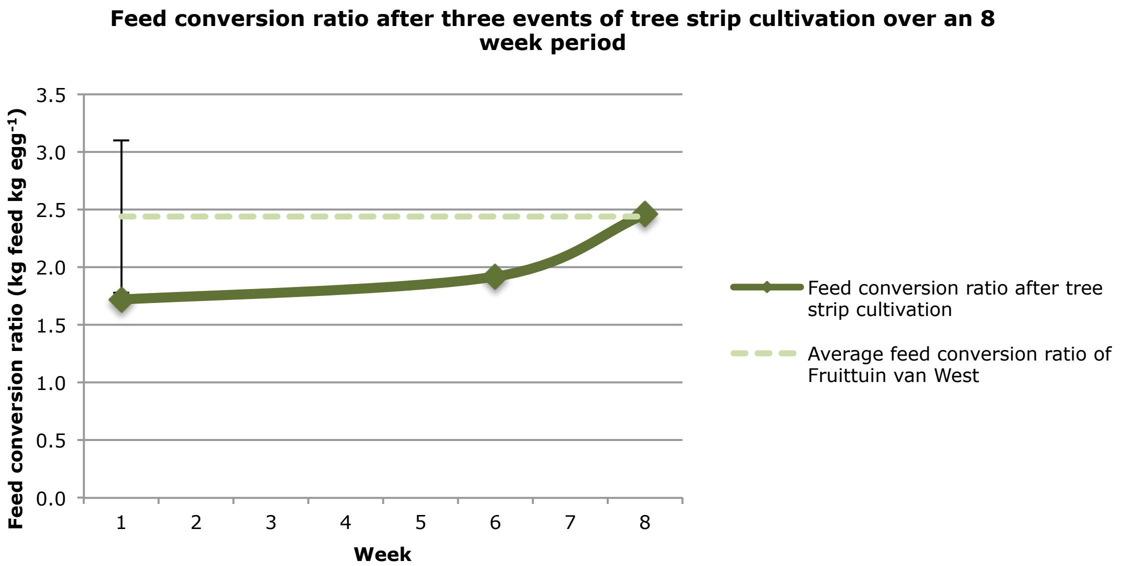

Figure 10: Feed conversion ratio after three recurrent tree strip cultivation events (week 1, 6 and 8) in one location in the orchard where chickens were present at the time of measuring (dark green line) with the average feed conversion ratio without tree strip cultivation (dashed light green line) and its 95% confidence interval

Prior to cultivation, the number of earthworms was higher in the location where chickens were present at the time of measurements (25 per 8 dm^3, SD = 7.7) compared to the location where chickens had not been present (14 per 8 dm^3, SD = 6) ($P<0.05$). Yet, the average weight of earthworms in the location where chickens were present at the time of measurements was lower (0.24 g $earthworm^{-1}$, SD = 0.05) compared to the average weight of earthworms in the location where chickens had not been present (0.33 g $earthworm^{-1}$, SD =0.06) ($P<0.05$). When the average weight per worm was multiplied with the number of earthworms counted in every sample, earthworm biomass was not significantly different between the two locations, though there was a shift towards higher earthworm biomass in the location where chickens were present at the time of measurements compared to the location where chickens had not been present (Figure 11).

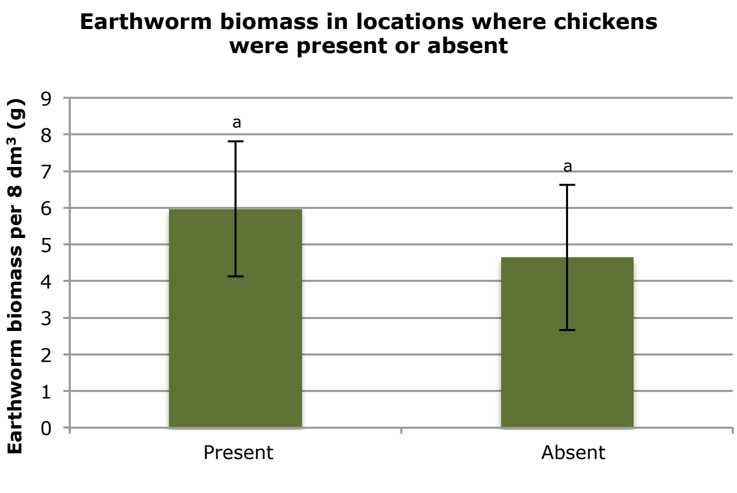

Figure 11: Average earthworm biomass per sample (8 dm^3 soil sample) in the locations where chickens were present at the time of measurements for a period of 4 weeks (Present) and where chickens had not been present before (Absent). Different letters indicate statistical significance at the 0.05 level.

After one day of tree strip cultivation, the number of earthworms in the location where chickens were present at the time of measurements tended to be lower (36%) compared to before cultivation (P<0.10). Contrarily to this finding, in the location where chickens had not been present, an increase of 56% of the number of earthworms was found after one day tree strip cultivation took place compared to the measurements taken prior tree strip cultivation (P<0.05). Nine days after cultivation, the number of earthworms had not significantly changed in number in both locations compared to one day after cultivation. However, for the location where chickens were present at the time of measurements, earthworms showed a marginal recovery to their original number before tree strip cultivation was carried out. After sixteen days, the number of earthworms at the location where chickens were present still had not increased significantly compared to one day after cultivation (Figure 12).

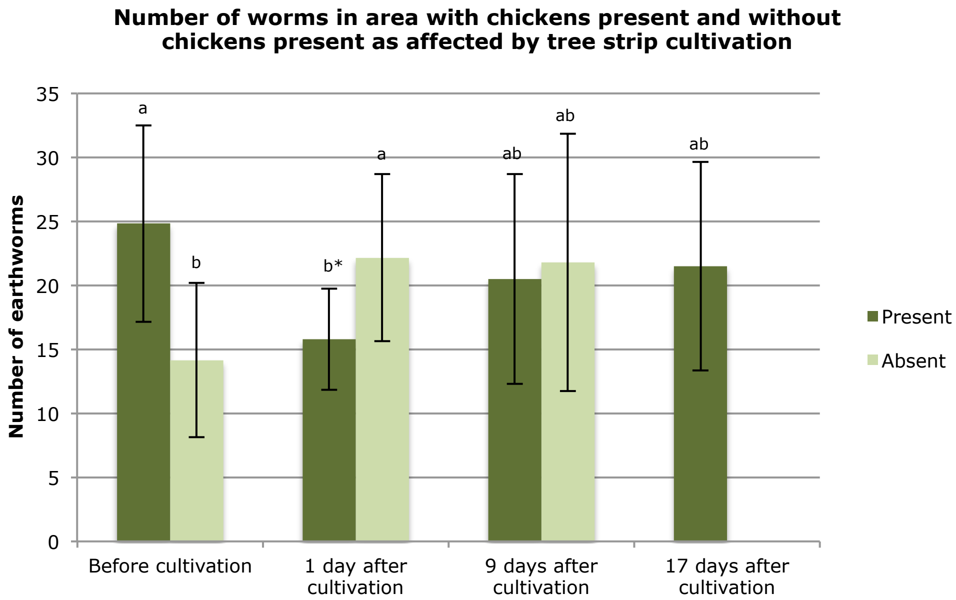

Figure 12: Number of earthworms as affected by tree strip cultivation in areas where chickens were present at the time of measuring (Present); dark green bars) and where chickens had not been present (Absent; light green bars) 1 day before and 1, 9 and 17 days after tree strip cultivation. Different letters indicate statistical significance at the 0.05 level, (letter)* indicates significance at the 0.10 level.

3.3. Animal behaviour

The most commonly noted behaviours for hybrid laying hens in the Fruittuin van West were foraging, walking and comforting behaviours like grooming, resting and sun-/dust bathing, adding up to 79% of the total time observed. Compared to battery and deep litter housing systems, laying hens in the Fruittuin van West showed less standing behaviour (Δ 65% and Δ 42%, respectively). Chickens in the Fruittuin van West performed more foraging and comforting behaviours compared to battery and deep litter stables. The percentage of time spent on walking of laying hens in the Fruittuinvan West was more compared to battery systems but similar to chickens in deep litter stables.

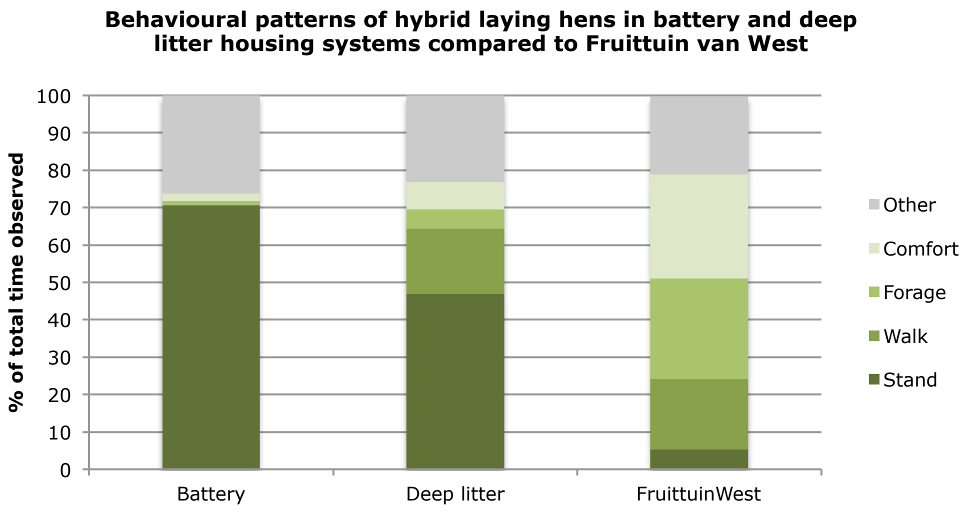

Figure 13: Graphical representation of time spent on standing, walking, foraging, comforting behaviours and other behaviours of hybrid laying hens in battery, deep litter stable systems (Mollenhorst et al., 2005) and of hybrid laying hens in the Fruittuin van West.

Chicks of the dual-purpose breed raised in the orchard by mother hens showed to have a similar behaviour pattern compared to the general behaviour pattern of adult hybrid laying hens in the Fruittuin van West. Chicks of the dual-purpose breed raised by mother hens were only found to spend more time on resting ($P<0.05$; 24% versus 9% respectively). Compared to chicks raised without mother hens, chicks raised by mother hens spend more time on foraging ($P<0.05$; 24% versus 10%) and less on eating ($P<0.05$; 7% versus 22% respectively). Furthermore, chicks raised by mother hens tended to spend more time on walking compared to chicks raised without mother hens ($P<0.10$) (Figure 14).

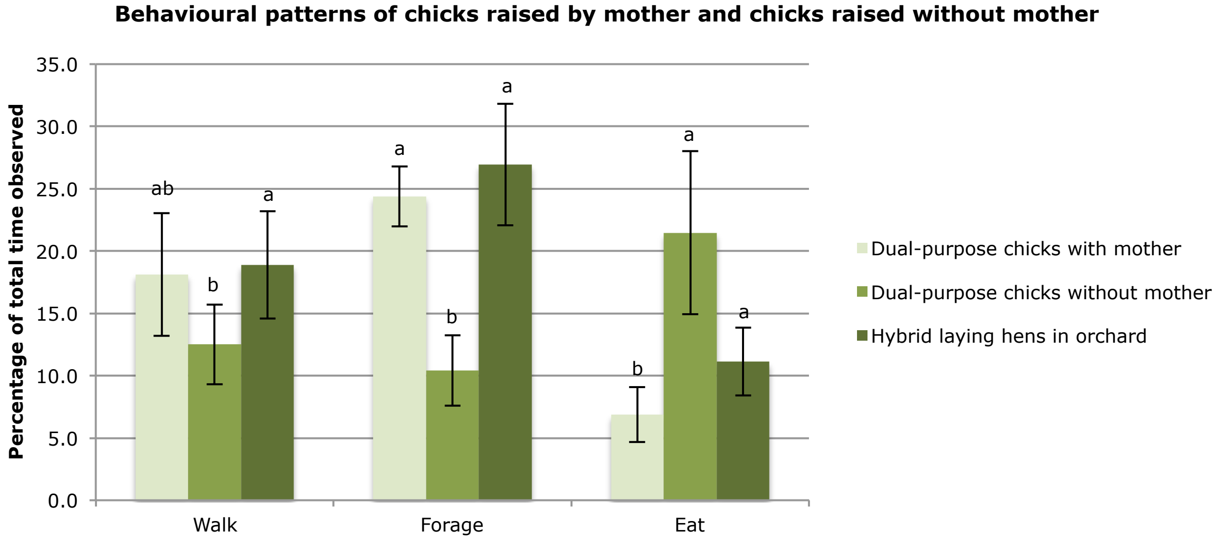

Figure 14: Graphical representation of time spent on walking, foraging and eating by chicks of the dual-purpose breed raised by mother hen in the orchard from 3 to 6 weeks of age (light green) and chicks of the dual-purpose breed raised without a mother in a stable of similar age (darker green) compared to the hybrid laying hens in the orchard (dark green). Different letters indicate statistical difference at the 0.05 level for each behaviour.

3.4. Maternal care

From the seven introduced Orpington hens, a total of four got broody before the eggs hatched. The onset of broodiness for two out of four hens was at the first day when the eggs were put in the incubator. Therefore, these hens were broody for the entire 21 days before the eggs hatched. For the other two hens, onset of broodiness was at day 12 and at day 19, respectively (Figure 15).

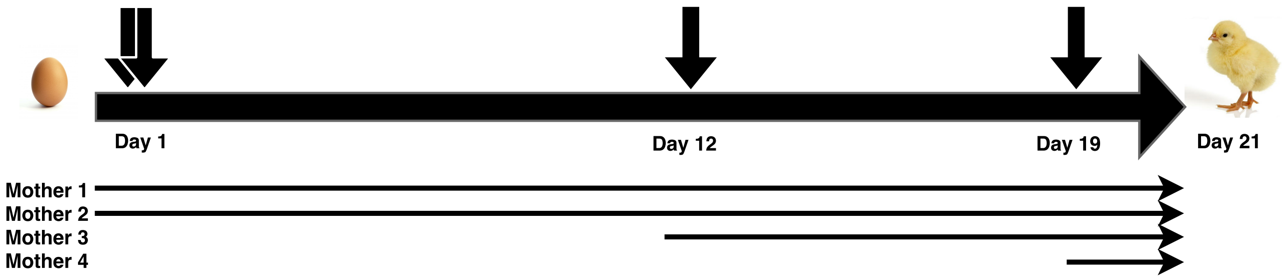

Figure 15: Onset of broodiness of four Orpington hens (thick vertical black arrows) during the time of incubating eggs until the chicks hatched (thick horizontal black arrow) and total length of broodiness period of each mother hen (thin horizontal arrows)

A total of 434 eggs out of 499 contained an embryo at 18 days of incubating. From the 434 fertilized eggs a total of 60 were put under the mother hens in their laying nests, leaving 373 eggs still in the incubator. From the 373 fertilized eggs 76% (284) hatched. From the 30 eggs put under the two mother hens that were broody for 21 days, hatchability was found to be 85%. From the other two mothers that were broody at 12 and 19 days, hatchability was only 13% and 7% respectively. All hens accepted 1-day-old chicks from the incubator. The hen that got broody at 19 days after the incubator was installed appeared to show no typical broody hen behaviours and vocalizations. Therefore, it was decided to provide this hen with a total of 10 chicks rather than 15 (Figure 16).

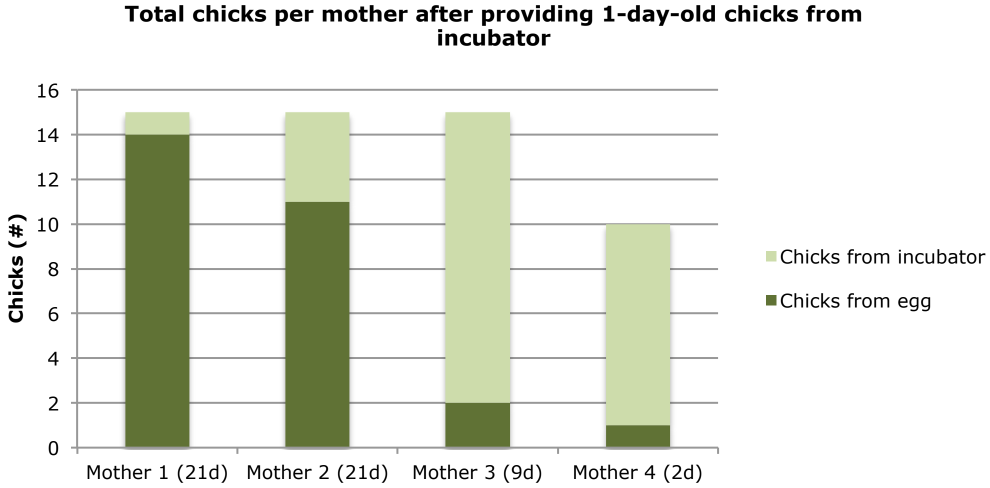

Figure 16: Hatchability for each of the four mother hens from 18-day-old fertilized eggs (dark green bars) with broodiness period between brackets and the number of 1-day-old chicks added from the stable (light green bars) until total number of chicks was 15, except for mother hen #4 (n=10)

During the time mother hens and their chicks were housed in wooden boxes a rat took a total of 25 chicks, reducing the total number of chicks to 30. After reintroducing the mother hens and their chicks in the orchard, another 5 chicks were taken but from an unknown cause. It might have been possible that the farmer's dogs took these chicks, since it was found to be a common issue that the dogs chased adult chickens.

Feed consumption of chicks was higher for chicks raised with mother hens compared to chicks raised without mother hens before adapting feeding boxes to reduce spillage and feeding by the mother hens (week 2: 40 g chick^{-1} day^{-1} versus 15 g chick^{-1} day^{-1}). At 3.5 weeks of age, after adaptations of the feeding boxes, chicks raised by mother hens were found to have a similar feed consumption compared to chicks raised in the stable without mother hens (69 g chick^{-1} day^{-1} for both rearing systems) (Figure 17).

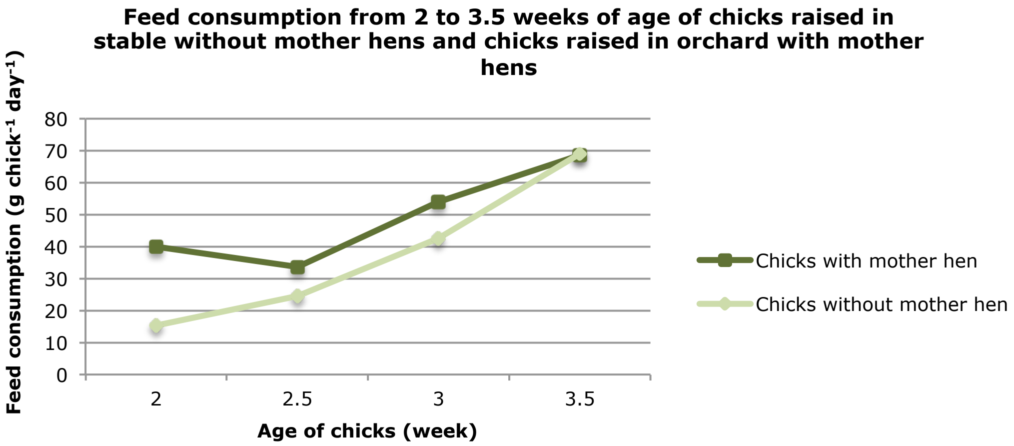

Figure 17: Feed consumption (g chick^{-1} day^{-1}) of chicks raised by mother hens in orchard (dark green) and chicks raised without mother hen in stable (light green). Feed troughs of chicks raised with mother hens in the orchard were adapted during the measurements to reduce spillage and feeding by mother hens.

Growth rate of chicks during the first weeks of age (week 1 to week 4) showed a tendency for chicks raised in stable without mother hens to be higher than for chicks raised in the orchard by mother hens. At 4 weeks of age, chicks raised in the stable without mother hens had a 21% higher weight ($P<0.05$) than chicks raised in the orchard by mother hens (Figure 18). At 14 weeks of age, after all chicks had been introduced to the orchard for 9 weeks (chicks raised by mother hens in orchard) and 6 weeks (chicks raised in stable without mother hens), chickens showed no statistically significant difference anymore between the two groups (1200 g chicken^{-1} versus 1216 g chicken^{-1}, respectively, appendix 3).

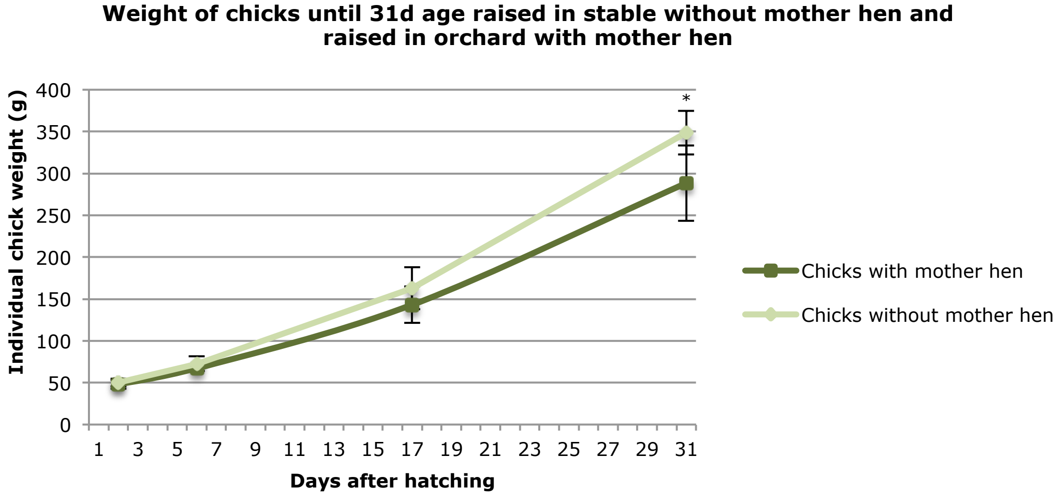

Figure 18: Weight increase of chicks (g) raised by mother hens in the orchard and raised without mother hens in stable from age day 1 until age day 31. * indicates statistical significance at the 0.05 level.

3.5. Dual purpose breeds

Calculations based on the parameters as specified in section 2.5 showed that 500 chickens reared from hybrid broilers (n=125) and hybrid laying hens (n=375) resulted in a production of about 90.000 eggs, 150 kg meat from broilers and 120 kg meat from slaughtered laying hens per year. This was calculated to result in a total turnover of about €26,000.- (rounded up to €500.-), based on prices of €0.25 per egg, €12,- per kg broiler meat and €10,- per kg hybrid laying hen meat. Within this calculation a mortality of 20% was taken into account, which was based on the recorded data on the number of chickens in the orchard over a period of 17 weeks.

Costs for the hybrid breed model comprised buying laying hens (€7,- laying hen^{-1}) and broiler chicks (€0.50 chick^{-1}) (Wil Sturkenboom, personal communication, June 30, 2016), feed for broiler chicks (6.3 kg at €0.45 kg^{-1}), feed for laying hens (120 g day^{-1} at €0.35 kg^{-1}), depreciation of buildings (estimated to be €430,- year^{-1}) and labour (0.5 hrs. day^{-1} at €15,- hr^{-1}). This resulted in total costs adding up to about €10,500.-.

500 chickens reared from the dual-purpose breed (n=375 laying hens and n=125 cockerels) resulted in a production of about 71.000 eggs, 150 kg meat from cockerels and 150 kg meat from slaughtered laying hens. This would result in a total turnover of €21,000.-, based on the same prices compared to hybrid breeds and with a mortality of 20%.

Costs for the dual-purpose breed model comprised brooding (€0.65 per chick), feed for raising laying hens (7.0 kg at €0.38 kg^{-1}), feed for raising cockerels (7.0 kg at €0.38 kg^{-1}) and feed for laying hens at adult age (120 g day^{-1} at €0.35 kg^{-1}). Depreciation of buildings was calculated to be the same and labour requirement was assumed to be similar compared to using hybrid breeds. This resulted in total costs adding up to about €8,500.-.

Subtracting costs from revenues resulted in about an 18% lower net income when rearing dual-purpose (€12,500.- $year^{-1}$) compared to rearing hybrid breeds (€15,000.- $year^{-1}$) (Table 5).

Table 5: Financial summary of rearing a total of 500 chickens of hybrid breeds in orchards versus rearing dual-purpose breeds with on-farm propagation by mother hens in orchards. Calculations were based on 20% mortality for both rearing systems.

	Hybrid laying hens (# 375)	Broilers (# 125)	Dual-purpose laying hens (# 375)	Dual-purpose cockerels (# 125)	Unit
Income					
Eggs	90.000	-	71.000	-	# $year^{-1}$
Price	0.25	-	0.25	-	€ egg^{-1}
Meat	120	150	150	150	kg $year^{-1}$
Price	10	12	10	12	€ kg^{-1}
Turnover	26.000		21.000		€ $year^{-1}$
Costs					
Buying/brooding chick(en)s	7.0	0.5	0.67	0.67	€ $chick(en)^{-1}$
Feed chickens until adult/slaughter age	-	7.0	7.0	6.3	kg $chicken^{-1}$
Cost feed until adult/slaughter age	-	0.45	0.38	0.38	€ kg^{-1}
Feed adult laying hens	120	-	120	-	g day^{-1}
Costs (incl. depreciation and labour)	10.500		8.500		€ $year^{-1}$
Net income	15.500		12.500		€ $year^{-1}$

4. Discussion

4.1. Housing

Compared to static housing systems, using mobile chicken coops lead to lower trampling effects and decrease N leaching potential (Antonissen & Lantinga, unpublished). In the present study, mobile chicken coops were used that allow direct manure deposition on the soil below the chicken coop. This reduces labour demand for collecting manure and cleaning chicken coops and might improve air quality in the chicken coop because of lower ammonia concentrations (Bestman et al., 2011). Furthermore, these chicken coops are relatively lightweight and can therefore be easily relocated.

When using mobile chicken coops that allow fertilization directly on the soil, manure was found to be relatively concentrated with an average N fertilization equivalent to 85 kg N ha^{-1} $year^{-1}$ with a density of 267 chickens 24 m^{-2} after one night. Chickens were found to have a preference for spending their night in the chicken coop that was consistently closest to the starting position. This effect might be attributed to the natural behaviour of chickens to go back to their original sleeping location, though there is no literature supporting this hypothesis. Since chicken coops are relocated daily, the movement of their sleeping locations may therefore induce a higher number of chickens to sleep in the chicken coop that is always closest to the starting position in the fenced-off area. As a result, a heterogeneous manure deposition was found every other three rows in the orchard, ranging from an average of about 37 to 130 kg N ha^{-1}. Regular relocation of chicken coops with direct manure deposition on the soil is therefore important in order to minimize N leaching and within this study it is suggested that relocation should take place every day.

The amount of N in chicken manure based on feed intake and N retention in eggs (Table 3) was calculated to be higher compared to the calculation based on manure collection (Table 2), but this difference was only 20 kg N ha^{-1} $year^{-1}$. In the calculation, feed intake was only based on supplied feed (concentrates and spelt grains), but feed that was taken up due to foraging activities was not taken into account. Herbage intake can be measured, as explained in Latinga et al. (2004), and could account for up to 10% of the daily DM intake for laying hens (Eyles, 1963). Besides, foraging on invertebrates is also a main important source of energy and protein intake for chickens (Hermansen et al., 2004). It may be possible that the total protein:energy ratio is lower when feed intake from the pasture, including invertebrates, is taken into consideration (Hermansen et al., 2004). If protein:energy ratio of the diet of chickens is lowered in the calculations, the N content of chicken manure based on feed intake also reduces. The reason for a lower protein:energy ratio compared to regular chicken rearing systems may be because of the fact that chickens in an outdoor pasture have a higher energy demand because of lower ambient temperatures and higher activity-related behaviours (van Krimpen et al., 2015b).

The amount of manure deposited under the chicken coop was measured in winter only. However, in winter, the nights are still long compared to summer at the latitude of the Netherlands. Since the deposition of manure is mainly found under the chicken coop, the total manure concentration in summer under the chicken coops is expected to be lower compared to winter. The expected higher manure deposition in winter is disadvantageous, because of a higher N leaching potential (Di & Cameron, 2002). To manage this issue, in winter, chicken coops could be adapted such that manure can be collected. For this, a lightweight board covering the underside could be added to the chicken coop. On top, straw can be provided and the obtained solid manure provides a source of organic fertilizer that can be distributed throughout the orchard later in the season.

The chicken coops as used on the farm are relatively simple structures. The downside of this design is that predation may occur due to insufficient measures to prevent predators from entering the coop. Currently, the farmer has an electric fence around his farm that has reduced incidence of predation already substantially, but predation is still experienced as an important issue. This has led to a mortality of 20% over a period of 17 weeks as measured in the present study, which is very high compared to other Dutch organic rearing systems (Leenstra et al., 2014). The incidence of predation was mainly due to foxes. A possible adaptation that could be implemented to the design of chicken coops is that the perches are lifted by means of a pulley to up to 2 meters high every evening, such that it is impossible for foxes to reach the chickens. The following morning, chickens can jump from the perch on the ground and perches can be put down again.

4.2. Feed

It was found in this study that feed conversion ratio was 2.3 kg supplied feed kg egg^{-1}, which is similar to Dutch organic chicken rearing systems (2.4 kg supplied feed kg egg^{-1}) (Leenstra et al., 2014). However, the feed provided to the chickens in the Fruittuin van West contained a 50% share of concentrates only and 50% spelt grains, which is a substantial lower amount of supplied proteins compared to a more regular diet for laying hens consisting of nearly 100% of concentrates (Bestman et al., 2011). When laying hens lack proteins in their diet, especially methionine, this may result in a lower laying percentage and reduced egg weight (Van Krimpen et al., 2015b). However, laying percentage of hybrid laying hens in the Fruittuin van West (84%) was comparable to Dutch organic chicken rearing systems (85%) as measured in the study of Leenstra et al. (2014) and average individual egg weight was 64 g. Therefore, it is suggested that when integrating laying hens in orchards the supplied feed can be reduced in share of proteins by means of replacing 50% of the amount of concentrates by e.g. spelt grains without risking dietary deficits.

Feed costs account for a relatively large share of total costs in chicken rearing systems, with up to 70% of the total variable costs of production (Walker & Gordon, 2003). Spelt grains are a relatively cheap resource compared to concentrates, so integrating chickens in orchards contributes to reduced costs for feeding. Moreover, the production of concentrates makes up a substantial part of the environmental pollution in the life cycle analysis of poultry rearing (Nguyen et al., 2010). The integration of chickens in orchards therefore reduces the impact on the environment.

As mentioned, an important part of the diets of chickens that forage in natural areas comprise invertebrates (Hermansen et al., 2004) and earthworms contribute to a major proportion of invertebrate biomass in the soil (Edwards, 2004). In the present study, the influence of foraging laying hens on earthworm biomass was assessed. Total earthworm weight seemed to be higher in the area where chickens were present compared to where the chickens were absent (Figure 11), but this was statistically not significant. Probably this was because the number of observations was too low because of a relatively high standard deviation between the samples ($n_{A,B}$ should be 27 at the found SD and difference). Reason for this hypothesis is that earthworms are attracted to organic amendments supplied to the soil surface (Edwards & Bohlen, 1996). When chickens fertilize the soil, earthworms are attracted as a result. However, at the same time, chickens are predating the worms and possibly the larger worms are preferred due to higher nutritious content. This may explain that individual earthworm weight in the presence of chickens was lower. So, although there is predation of earthworms by chickens, the net result might be that there are more earthworms attracted because the manure deposited is a feed source for earthworms.

When tree strip cultivation was practiced, the number of earthworms reduced after the first time of cultivation in the location where chickens were present. This can be explained by foraging of chickens. In the location where chickens were absent, earthworms increased in number. This can be explained by the fact that top soil disturbance attracts earthworms (Edwards & Bohlen, 1996). Recurrent cultivation in the location where chickens were present did not lead to a consistently lower feed conversion ratio over time. Rather, after recurrent tree strip cultivation on the same location, a clear pattern of higher feed intake from the supplied feed (concentrates and spelt grains) was found (Figure 10). Possibly, a lower amount of rewarding foraging opportunities (earthworms) was provided, because of recurrent cultivation on the same location. As a consequence, earthworms might not have been able to recover to their original number (Figure 12) and the decreasing availability of nutritious feed from the tree strip cultivation practices may have caused chickens to increase their feed intake from the provided feed (concentrates and spelt grains). After allowing a resting period of 17 days after the first time of tree strip cultivation, there were some indications of recovery, possibly due to migration of earthworms to the tree strip cultivated rows, because soil disturbance events attract earthworms (Edwards & Bohlen, 1996). This recovery is probably not a result from reproduction by earthworms, since their reproduction cycle takes about 10 weeks (Edwards & Bohlen, 1996).

Tree strip cultivation may only reduce the feed conversion ratio substantially when allowing sufficient resting periods. Therefore, tree strip cultivation may consequently not have a very high impact on reducing the average feed conversion ratio. To further assess the reduction of tree strip cultivation on the feed conversion ratio, follow-up experiments should allocate chickens to locations in an orchard that have had consistent tree strip cultivation histories and take recovery time of earthworms into account.

Chickens also forage on aboveground invertebrates (Hermansen et al., 2004; Koorn & Allmenröder, Appendix 1). Because of this, integrating chickens in orchards can potentially serve as pest control to reduce damaging insects that may occur in fruit trees (Hermansen et al., 2004). In a study done on pest control of apple saw flies by chickens resulted in a lower number of apple saw flies, but this had no effect on final fruit yield nor quality (Pedersen et al., 2002). However, Pedersen et al. (2002) studied broiler chickens, which are only kept for a relatively short time before they are slaughtered. As Pedersen et al. (2002) suggested, when introducing laying hens in orchards that stay during a whole year, the effect of pest control by chickens may be larger. Future studies could focus on the beneficial role chickens may have on pest control, thereby especially focussing on the increasing pest problem in orchards of *Drosophila suzukii* (Cini et al., 2012).

4.3. Animal behaviour

From the behavioural patterns of chickens in the Fruittuin van West orchard, foraging and walking comprised the largest share of behaviours. Besides, a large share of comfort behaviours was noted, which is less found in regular laying hen systems (Mollenhorst et al., 2005). The behavioural pattern of chickens in the orchard is more similar to the common ancestor of the domestic chicken red junglefowl (*Gallus gallus* L.) (Dawkins, 1989) compared to battery cage and deep litter systems (Mollenhorst et al., 2005). In this respect, the current rearing conditions and management practiced at the Fruittuin van West contributes to supporting living natural lives, following the focus of the organic sector of animal husbandry (Lund, 2006).

Chicks raised by mother hens in the orchard adopted the typical behaviour pattern of adult chickens. This was not the case for chicks raised without mothers in the stable. In the stable there are less opportunities for foraging compared to the orchard. Besides, it was observed that the mother hen plays an important role in guiding the chicks throughout the orchard, something that was also apparent in other studies (Edgar et al., 2016). Walking behaviour was therefore more common among chicks raised by mothers compared to chicks raised without mothers in the stable. Since chicks were found to spend more time on foraging, eating from the feeder was less observed. This pattern was similar to adult chickens in the orchard. These findings suggest that raising chicks by mothers in the orchard allows them to express more natural behaviours compared to chicks raised without mother hens in an indoor system.

The limitation of the comparison made in the present study between the chicken rearing systems was that the improvement towards more natural behaviour patterns of chickens in the Fruittuin van West was compared with conventional battery cage systems and deep litter stables only. The behaviour pattern of chickens in other organic chicken rearing systems should also be taken into account in order to determine whether the management practiced in the Fruittuin van West provides additional welfare benefits in terms of a more natural behaviour pattern. It could be hypothesized that chickens in the Fruittuin van West still show more similarities in their behaviour patterns to the red junglefowl compared to other organic rearing systems, because the chicken rearing management in the Fruittuin van West provides a relatively high share of cockerels in the flock, trees in the outdoor pasture and uses mobile chicken coops that allow chickens to make more use of the outdoor area (Wagenaar & Bestman, 2003). On top of that, the practice of rearing chicks by mother hens showed that chickens adopt this behaviour pattern at an early-life stage. Contrarily, current organic management practices introduce laying hens at the age of 18 weeks and during their raising period chickens are reared in conventional stables. Besides, organic broiler chicks also start their early-life period in indoor stables. Therefore, raising chicks by mother hens and implementing the management of the Fruittuin van West may contribute more to supporting living natural lives of chickens compared to current standard organic rearing systems.

4.4. Maternal care

Hatchability of eggs under the two mothers that were broody during the full period of 21 days (83%) was comparable to the incubator (76%). However, there was a large decrease in hatchability of eggs under the two mother hens that were broody for 9 and 2 days respectively (average hatching rate was 10%). This was thought to be due to the disruptive character of replacing imitation eggs for fertile 18-day-old eggs from the incubator, thereby stressing chickens resulting in trampling of eggs. Replacing imitation eggs by 18-day old eggs from the incubator or by one-day-old chicks in the night when broody hens are asleep can be a solution to increase hatching rate. Also, smaller incubators can be used to improve synchronization of hatching eggs for each broody hen.

During the first weeks of rearing, chicks are highly vulnerable to many predators. In the present study this resulted in a decrease of almost 50% of the population due to a rat and the population was reduced even more by the involvement of a dog. This high loss of chicks was considered as a result of miscommunication between the responsible people involved. If there was action undertaken to protect mother hens and their chicks at the first signs of predation, the high loss could have been largely prevented. Especially during the first weeks of age, raising chicks needs attention, even though chicks are already to a large extent taken care of by mother hens. Predation is regarded to be the main bottleneck for rearing chicks by mother hens in an orchard. Future studies should look for cost-effective measures to decrease losses to predators, thereby using firmly fenced-off areas where the mother hen and her chicks can be safely introduced.

Feed consumption of chicks raised without mother hens in the stable seemed to be lower compared to feed consumption of chicks raised by mother hens in the orchard. Spillage and consumption of feed by mother hens probably led to a high loss of feed meant for chicks only, because when feed was provided such that mother hens could not consume from this feed but only chicks could, feed consumption reduced. Therefore, to lower feed spillage when rearing chicks by mother hens, feed troughs should be adapted.

Chicks raised without mothers in the stable had a higher growth rate compared to chicks raised by mothers in the orchard. This was probably the result of both more activity-related observed behaviours and lower ambient temperatures in the outdoor chicks. This increased the energy requirements of chickens (Van Krimpen et al., 2015b), and may have led to a lower weight gain among the chicks raised by mothers in the orchard.

Earlier studies have identified direct positive cues mother hens provide to raising chicks (Bestman & Wagenaar, 2003; Rodenburg et al., 2009ab; Edgar et al., 2016). This study took a more integrative perspective and introduced chicks with mother hens in orchards in order to provide more natural living conditions. Although this resulted in a more natural behaviour pattern shown by chicks raised by mother hens compared to chicks raised in the stable, allowing chicks in the orchard led to substantial losses of chicks due to predation. Therefore, to make the integrative approach of raising chicks by mother hens in orchards a viable alternative to regular practices in indoor stables, sufficient protection measures are required. Future studies should be aimed at finding methods to effectively reduce losses due to predation, thereby taken into consideration that the natural habitat should remain intact. Also, the practice of raising chicks by mother hens in orchards can still be optimized concerning replacement of fertile eggs or one-day-old chicks to improve hatching rate.

Another aspect that has not been taken into consideration thus far is that mothers are known to transfer antibodies to their offspring (Boulinier & Staszewski, 2008). When chickens are propagated and raised on the farm by mother hens, vaccination of chicks may become therefore unnecessary, because of passive natural transmission of antibodies through the yolk sac (Boulinier & Staszewiski, 2008). Future studies could therefore identify to what extent vaccination in general or certain types of vaccins can be excluded if chicks are raised by mother hens.

4.5. Dual purpose breeds

Using dual-purpose breeds was estimated to result in an 18% lower net income compared to using hybrid breeds (Table 5). This lower income was mainly because of a lower egg production of laying hens of the dual-purpose breed (65%) compared to hybrid breeds (84%). When increasing the prices of direct sales of eggs of the dual-purpose breed from 25 cents to 30 cents, net income was modelled to be just as high. This leaves the question whether the consumer is willing to pay the price. Consequently, this leads the discussion for rearing dual-purpose breeds more towards a value-based decision rather than an income-based decision (Gocsik, 2014).

In fact, any orchard system would already produce more outputs if chickens were integrated, because there is no extra land needed for rearing chickens and chickens can be readily introduced without major adaptations other than acquiring relatively simple sleeping, laying and feeding/drinking facilities. Besides, since there is an ethical call for finding alternatives to large-scale culling of one-day-old male chicks among laying breeds (Ellendorf et al., 2003) and physical development issues among fast-growing broilers (Bessei, 2006), rearing dual-purpose breeds may be more supported by the society and by farmers rearing poultry according to organic standards compared to rearing hybrid breeds (Nauta et al., 2003).

Besides, as on-farm propagation and allowing adaptation of chickens to local conditions over generations is more in line with the values in organic agricultural systems (Luttikholt, 2007; Nauta et al., 2003; Lund, 2006), purebred dual-purpose breeds integrated in orchards with on-farm propagation may suit those systems better.

However, current initiatives to raise the cockerels of laying breeds for meat production seem promising (Lankerenhof, 2016). Besides, the physical development issues in slower-growing broiler breeds are already minimized compared to fast-growing broilers (Bessei, 2006). Therefore, dual-purpose breeds may not contribute substantially more to animal welfare than these implementations. On top of that, dual-purpose breeds still require a higher feed intake for the same meat or egg production compared to hybrid breeds, resulting in a higher environmental impact for rearing dual-purpose breeds (Ellendorf et al., 2003).

Yet, the present study has identified that the share of concentrates can be substantially lowered when rearing chickens in orchards and this finding is supported by other studies (Hermansen et al., 2004; Hughes & Dun, 1983). Therefore, if the comparison of feed use efficiency would be made on a more integral level between dual-purpose breeds and hybrid breeds, dual-purpose breeds may be more efficient. This is because hybrid breeds in indoor stables require a diet consisting of 100% concentrates. High-protein containing ingredients and ingredients originating from a global market (esp. soy and palm oil) contribute more to environmental pollution compared to locally-grown grains (Nguyen et al., 2012). The impact of dual-purpose breeds on the environment is currently based on indoor stables (Ellendorf et al., 2013), but a life-cycle assessment for rearing dual-purpose breeds in orchards may result in a more positive outcome compared to rearing hybrid breeds in indoor stables. Therefore, dual-purpose breeds integrated in orchards may be more efficient in the use of concentrates compared to hybrid breeds in indoor systems. Conclusively, integrating dual-purpose breeds in orchards with on-farm propagation by mother hens is therefore an environmental friendly and ethically sound rearing system.

4.6. Synthesis

Within the present study, several aspects involved in a fundamentally new approach for rearing chickens were examined. In order to get a more integral view on the processes involved when combining these aspects, the following section provides a synthesis (Figure 19).

Regarding mobile housing, due to their relatively light weight, mobile chicken coops as used on the farm can be easily relocated, which allows the farmer to allocate chickens to areas on the farm that can benefit from the functions that chickens provide. The mobile chicken coops used on the farm allow direct manure deposition on the sward, leading to a substantial degree of fertilization below the coop. This requires chicken coops to be relocated daily in order to minimize N losses to the groundwater. To reduce N leaching in winter, a board can be added to the bottom of the coop to collect manure and mix the manure with straw. The obtained solid manure can be distributed later in the season. When chicken coops are relocated daily, a relatively even spread of birds throughout the orchard is realized. This may lead to a relatively homogeneous degree of foraging on invertebrates and chickens may serve therefore as an important means to reduce pests in orchards (Pedersen et al., 2002). Another benefit of regular relocation of chicken coops is that in the new locations tree strip cultivation can be practiced in order to expose macrofauna in the soil, providing an important source of natural foraging opportunities (Hughes & Dun, 1983; Hermansen et al., 2004). The share of concentrates could effectively be reduced due to foraging opportunities, which results in a lower environmental impact of rearing chickens in orchards compared to rearing chickens in indoor stables (Nguyen et al., 2010). These aspects provide an interesting approach for rearing purebred dual-purpose breeds, because of lower costs as a result of reduced share of proteins in the supplied diet and because of its contribution to a more ethical responsible way for rearing chickens (Nauta et al., 2003; Ellendorf et al., 2003; Bessei, 2006). Orchards allow chickens to express their natural behaviours and on-farm propagation by mother hens can be realised. This leads chicks to express natural behaviours already at a young age and possibly reduces need for vaccination (Boulinier & Staszewski, 2008). Animal welfare is therefore enhanced from the perspective of providing natural living conditions (Fraser, 2003; Lund, 2006). However, predation of chickens by foxes and rats remains the main bottleneck for adopting this practice. A possible redesign for chicken coops can be to lift perches up to 2 meters to prevent foxes from reaching chickens.

Overall, introducing poultry in orchards increases production per unit of area, because in regular orchard production sward strips between the tree lines remain unused. The farming system produces more diverse products as a result.

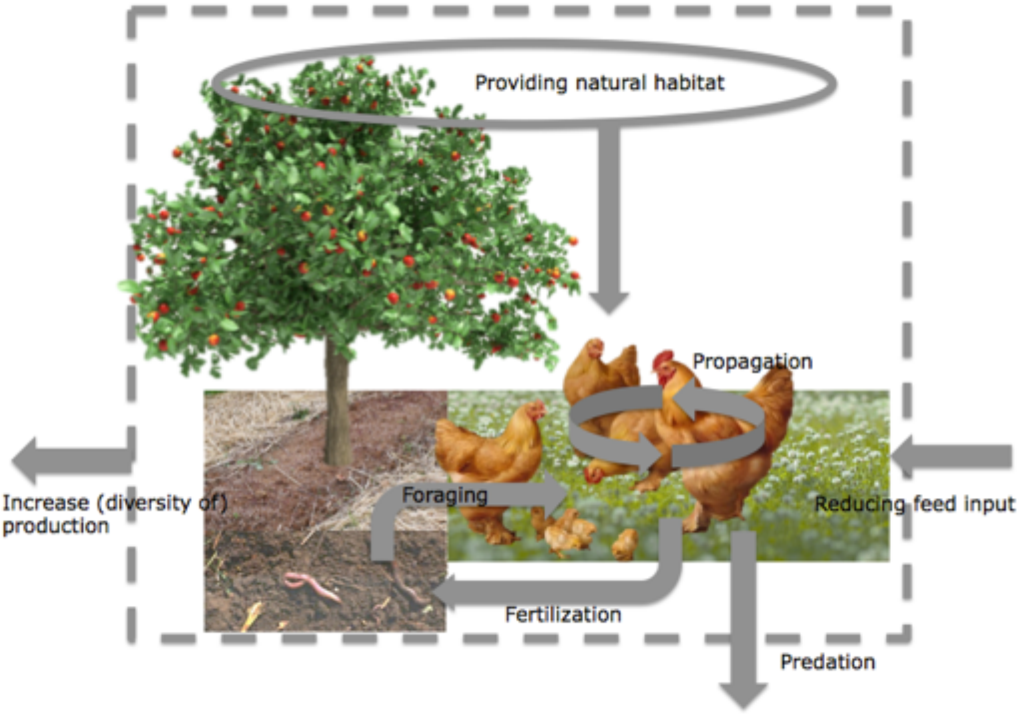

Figure 19: Overview of the main relationships when integrating poultry in orchards as found in the present study. Arrows indicate the relation to the (sub) system and the dashed square indicates the system boundary.

The position of the organic sector to focus on providing natural habitats has been criticized by disregarding other aspects of animal welfare (Lund, 2006), arguing organic chicken flocks tend to have higher mortality rates (Leenstra et al., 2012; Lervik et al., 2007; Hermansen et al., 2004). The present study confirmed this. However, if welfare would be understood as a concept in which chickens live natural lives (Fraser, 2003), then from this study it could be concluded that the welfare in an orchard system is higher compared to indoor systems. On top of that, allowing hens to become broody is part of their natural being (Edgar et al., 2016), making this system supporting the focus of organic husbandry even more compared to regular organic systems. Yet, animal welfare can also be understood as reducing animal suffering and good biological functioning (Fraser, 2003), where predation rates are decreased to a minimum level and production levels are maximised. In the latter case, raising chickens inside a protected housing facility meets the requirements better, since mortality is higher in outdoor systems (Leenstra et al., 2012).

For both outdoor and indoor systems to optimize welfare there are still challenges. Yet, often investments to improve animal welfare in indoor systems require price premiums before farmers are willing to adopt them (Gocsik, 2014). The middle-market segment gives therefore more interesting opportunities for farmers that have the motivation to increase animal welfare, because they are financially still attractive (Gocsik, 2014).

In an outdoor system, profitability of rearing dual-purpose chickens should be sought in diversifying the farming system such that it produces other outputs than chicken related products only. Integrating chickens in orchards using on-farm propagation provides a profitable basis for rearing dual-purpose breeds, because the system is not dependent on solely eggs or meat. This makes this practice suitable for farming systems aiming for diversification, which is one of the strategies for enhancing stable and resilient agriculture (ten Napel et al., 2006; Funes-Monzote et al., 2009). These aspects provide another profitable basis for rearing chickens by which animal welfare is enhanced, apart from the middle-market segment (Gocsik, 2014).

Yet, because of its extensive nature, poultry integrated in orchards has potentially a lower impact on increasing animal welfare in general compared to large-scale poultry production. In large-scale rearing systems, small improvements contribute more to animal welfare in general compared to transition-based small-scale rearing systems. Certain elements of the small-scale rearing system as postulated in this report can be identified and implemented in large-scale poultry production. For instance, provisioning of a more natural diet comprising of insect feed may lower the environmental impact of using concentrates (Wagenaar & Visser, 2006). Furthermore, a certain percentage of the cockerels of the laying breed can be introduced in the chicken flock and raised for meat production, which contributes to the ethical call for finding alternatives to one-day-old male chick culling (Ellendorf et al., 2003) and also contributes to reduced feather pecking (Wagenaar & Bestman, 2003). Also, as Edgar et al. (2016) already pointed out, artificial features of maternal care can be determined and implemented in large-scale rearing systems for raising chicks to improve their welfare, like dark brooders.

Still, there may be many farmers operating on an extensive small-scale basis that aim to diversify the farming system (van der Ploeg, 2000), making the practice of integrating dual-purpose chickens in orchards with on-farm propagation as presented in this study for those systems an interesting approach. Future studies could make an inventory of farmers that may be willing to adopt the practice of rearing dual-purpose breeds in orchards with on-farm propagation.

5. Conclusions

The practice of introducing chickens in orchards has not gained much attention in the Netherlands, but may provide solutions to challenges current practices face, especially those following organic standards. This study focused on the main interrelationships that result from a fundamentally new approach for rearing chickens. Using mobile housing systems with direct manure deposition and relocating them regularly leads to sufficient fertilization of the sward and a homogeneous spread of chickens throughout the orchard. This leads to higher foraging opportunities, including predation of earthworms and possibly damaging insects. The share of concentrates in the diets of chickens could therefore effectively be reduced down to 50% and this can be replaced with e.g. spelt grains to meet the increased metabolizable energy demands as a result of lower ambient temperatures and increased activity-related behaviours. Integrating purebred dual-purpose chickens in an orchard system with on-farm propagation by mother hens seems to be a promising approach for enhancing animal welfare from the perspective of living natural lives, provides a lower environmental impact compared to hybrid breeds in indoor systems and contributes to an ethically sound practice. Still, further research is needed to find options to reduce predation of chickens, which is considered the main bottleneck for implementing the redesigned chicken rearing system. Because of its extensive nature, poultry integrated in orchards has potentially a lower impact on increasing animal welfare in general compared to small improvements implemented in large-scale poultry production. Such incremental improvements can be derived from the current studied poultry rearing system. Nevertheless, the chicken rearing system as analysed in the present study is suggested to be a promising approach for extensive small-scale farming systems aiming to increase diversity of products.

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