Exploring barriers and opportunities for utilization of dairy cattle manure in agriculture in West Java, Indonesia

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In West Java, Indonesia, most dairy farmers are currently discharging cattle manure into the environment, causing environmental pollution and local nuisance. In this study we explored barriers and opportunities for increased utilization of dairy cattle manure in agricultural sectors in West Java. Interviews were conducted with dairy cooperatives, provincial governments, and a number of potential large-scale users of cattle manure. Results give insight in current manure management issues and initiatives, and perceived constraints and opportunities for increased utilization of cattle manure by these stakeholders. The horticultural sector, tea and coffee plantations, and forestry areas in West Java were identified as potential large-scale users of dairy cattle manure, but various practical, economic and organizational constraints need to be overcome.

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Summary (Bahasa)

Di Provinsi Jawa Barat, Indonesia, kebanyakan peternak sapi perah membuang limbah ke lingkungan. Pemanfaatan limbah sapi perah di sektor pertanian berpotensi mengurangi polusi lingkungan dan gangguan lokal yang ditimbulkan dari limbah peternakan yang dibuang. Penelitian ini bertujuan menganalisis hambatan dan peluang untuk meningkatkan pemanfaatan limbah sapi perah sebagai pupuk atau bahan tambahan tanah di sektor pertanian di Provinsi Jawa Barat, Indonesia. Wawancara dilakukan dengan berbagai pemangku kepentingan terkait, yaitu 5 (lima) koperasi besar di Provinsi Jawa Barat, perwakilan dari berbagai sektor pertanian (kopi, hortikultura, dan kehutanan), dan pemerintah. Sebagai tambahan, dilampirkan juga telaah pustaka singkat terkait karakteristik sektor pertanian di Jawa Barat, potensi manfaat dan kekurangan dari penggunaan limbah peternakan sebagai pupuk atau bahan tambahan tanah.

Dampak dari pengelolaan limbah yang buruk
Perwakilan dari koperasi peternakan sapi perah menduga 60%-90% limbah sapi perah dibuang. Kelebihan nutrien yang berasal dari limbah dan selanjutnya dibuang akan menyebabkan eutrofikasi, dan akan menyebabkan terjadinya kontaminasi sumber air minum. Koperasi peternakan sapi perah mengindikasikan adanya gangguan lokal (misalnya terganggunya masyarakat sekitar dari limbah yang tertumpuk atau dibuang ke lingkungan mereka) merupakan permasalahan utama, sementara koperasi peternak sapi perah lainnya mengindikasikan polusi terhadap pencemaran air, alam, dan lahan padi sebagai isu terkait buruknya pengelolaan limbah peternakan. Isu polusi merupakan isu yang spesifik, tergantung dari lokasi geografi dan aktivitas ekonomi lokal (misalnya pencemaran sungai dan pariwisata di Lembang, produksi padi di Kuningan). Hal ini menunjukkan perlu adanya penyesuaian solusi berdasarkan isu dari daerah masing-masing.

Potensi manfaat dan kekurangan dari penggunaan limbah peternakan sebagai pupuk
Mengaplikasikan limbah sapi perah berarti mengaplikasikan bahan organik yang kaya akan nutrien makro (N,P, K) dan nutrien mikro yang dibutuhkan oleh tanaman untuk tumbuh, dan dapat berkontribusi terhadap properti dan komposisi kimia, fisik, dan biologi tanah. Makro nutrien bisa ditambahkan dari pupuk kimia yang memiliki konsentrasi lebih padat dibandingkan limbah sapi perah. Pemangku kepentingan yang diwawancarai dalam penelitian ini menekankan nilai manfaat dari limbah peternakan sapi perah yang kaya akan bahan organik dibandingkan pupuk kimia dan limbah peternakan dari ayam yang kaya akan N dan P. Kami menduga sekitar 30 ton/ha limbah sapi perah atau 25 ton/ha limbah peternakan ayam diperlukan untuk menjaga level bahan organik di dalam tanah. Hal ini sejalan dengan rekomendasi pemupukan organik untuk tanaman pertanian (20-30 ton per ha), tetapi nilai rekomendasi ini lebih tinggi dibandingkan dengan kondisi di lapangan (13-17 ton/ha). Pemeliharaan bahan organik sepertinya belum menjadi prioritas petani karena memperbaiki produktivitas tanah dengan menggunakan limbah sapi perah membutuhkan lebih banyak waktu, sementara petani membutuhkan hasil pertanian yang cepat untuk memenuhi kebutuhan pasar yang semakin meningkat. Berdasarkan rekomendasi, jumlah kebutuhan nutrien dari pemupukan lebih tinggi dibandingkan dengan kebutuhan dari nutrien yang dibutuhkan oleh tanaman dan hal ini dapat diketahui melalui nutrien di dalam produk yang dihasilkan. Hal ini mengindikasikan bahwa rekomendasi pemupukan terlalu tinggi jika dikaitkan dengan suplai dari makro nutrien, sementara angka rekomendasi pemupukan untuk bahan organik sesuai dengan perhitungan yang kami lakukan untuk memelihara kebutuhan bahan organik di dalam tanah.

Salah satu kekurangan dari bahan organik dari limbah peternakan adalah kandungan nutrien dari bahan organik menunjukkan variasi yang besar dan sering kali tidak diketahui. Informasi mengenai kandungan bahan organik sangat penting, sehingga petani bisa memutuskan seberapa besar pupuk organik dan pupuk kimia yang dibutuhkan. Hal yang sama terkait tidak adanya kepastian terkait dengan waktu yang dibutuhkan untuk melepaskan nutrien dari bahan organik. Limbah sapi perah juga memiliki risiko kontaminasi terhadap pakan atau pangan yang dihasilkan, misalnya parasit atau patogen. Limbah sapi perah segar dapat memberikan dampak negatif terhadap tanaman hortikultura

ketika diaplikasikan dengan sistem mulsa, tetapi tidak jika limbah ditebar dan dicampur-adukkan ke dalam tanah sebelum dilakukan penanaman. Kebanyakan sektor pertanian menggunakan limbah dari peternakan ayam (postal) sebagai pupuk organik. Dibandingkan dengan limbah sapi perah, limbah ayam memiliki lebih banyak konsentrasi nutrien (termasuk asam urik N yang lebih cepat dapat diserap oleh tanaman), dan lebih punya banyak manfaat praktis meliputi lebih mudah didapatkan, membutuhkan biaya transportasi yang lebih sedikit, dan tersedia sepanjang waktu. Manfaat yang didapatkan dari penggunaan limbah sapi perah dibandingkan limbah ayam adalah limbah sapi perah yang sudah “dingin (fermentasi)” tidak akan membakar tanaman.

Potensi pemanfaatan limbah sapi perah oleh sektor pertanian skala besar
Koperasi peternakan sapi perah mengidentifikasi sektor pertanian yang dapat menyerap limbah sapi perah dalam skala besar: hortikultura (3 koperasi), teh (2 koperasi), kopi (1 koperasi), dan kehutanan (1 koperasi). Perbedaan pandangan koperasi memberikan indikasi bahwa penentuan sektor pertanian bersifat spesifik berdasarkan area di mana koperasi peternakan sapi perah berada, dan hal ini juga terkait komoditas tertentu di area tersebut. Keempat sektor pertanian yang diidentifikasi berdasarkan koperasi peternakan sapi perah, menggunakan lahan lebih dari 900,000 ha di Provinsi Jawa Barat (602,532 ha kehutanan, 164,338 ha sayuran dan rempah-rempah; area untuk tanaman buah tidak dihitung, 90,499 ha teh, 47,082 ha kopi). Hanya sebagian area dari area kehutanan yang bisa dimanfaatkan untuk aplikasi limbah peternakan. Kami mengasumsikan level aplikasi pupuk organik sebesar 18 ton/ha/tahun untuk tanaman kopi dan teh, 15 ton/ha/tahun untuk sayuran dan rempah-rempah, Kami menduga secara teoritis sekitar 5 juta ton dari pupuk organik dapat diaplikasikan pada lahan kopi, teh, sayuran dan rempah-rempah. Jika mempertimbangkan jumlah aplikasi 20 ton/ha/tahun pada sayuran dan rempah-rempah, nilai ini akan lebih tinggi lagi.

Pandangan pemangku kepentingan terkait dengan hambatan penggunaan limbah sapi perah
Menurut koperasi sapi perah, hambatan utama dalam pemanfaatan limbah sapi perah di lahan milik petani adalah lahan yang terbatas untuk aplikasi limbah peternakan, juga jarak dari kandang ke lahan. Tidak terintegrasinya lahan dan kandang menjadikan biaya transportasi menjadi mahal, dan biaya untuk tenaga kerja dan pakan, membuat penggunaan limbah sebagai pupuk menjadi sangat sulit. Hambatan lain adalah tidak adanya pasar limbah dan manfaat ekonomi yang kecil dari penjualan limbah. Menurut beberapa koperasi sapi perah, belum ada kesepakatan formal antara peternak sapi perah dan petani, menjadikan ketidakpastian pasokan limbah sapi perah baik bagi pemasok maupun pembeli.

Hambatan yang diindikasikan oleh pengguna skala besar adalah biaya, kualitas limbah, kemudahan dalam penanganan, pengangkutan dan aplikasi, serta ketersediaan limbah secara kontinu. Hal ini sejalan dengan survei skala besar yang dilakukan pada petani hortikultura di Lembang, yang mengindikasikan bahwa isu utama dari limbah sapi perah adalah kesulitan dalam transportasi limbah, limbah terlalu basah, biaya transportasi yang tinggi, limbah tidak dikemas dengan baik, dan kesulitan dalam penanganan dan aplikasi (Pronk et al., 2020). Hal ini menunjukkan bahwa sektor peternakan sapi perah perlu mengembangkan dan memperbaiki pengelolaan limbah sapi perah yang mudah diangkut dan diaplikasikan oleh pengguna akhir, dan menjamin suplai yang berkelanjutan. Pemerintah menekankan bahwa aturan pengelolaan limbah tidak bisa diterapkan kepada peternak kecil dan menekankan kesadaran bagi peternak sapi perah sebagai sebuah hambatan.

Pandangan pemangku kepentingan terhadap peluang pemanfaatan limbah sapi perah
Pengguna skala besar secara umum mempunyai pandangan yang positif terhadap penggunaan limbah sapi perah. Beberapa peluang untuk meningkatkan penggunaan limbah sapi perah antara lain : (1) sosialisasi dan pendidikan untuk peternak sapi perah dan pengguna akhir, (ii) berbagai solusi teknis untuk pengumpulan, penyimpanan, pengolahan (pengeringan), dan transportasi, dan (iii) kesepahaman formal antara pemasok limbah dan pengguna limbah. Isu teknis terutama terkait dengan pengeringan limbah sapi perah yang relatif lebih basah yang seharusnya bisa difasilitasi dengan tujuan agar limbah sapi perah lebih mudah ditangani dan lebih mudah diangkut, meliputi : Pengumpulan (*collection*) seperti menggunakan sistem pipa komunal, menjemput limbah dari peternak, penyimpanan (*storage*) seperti sistem penyimpanan komunal, dan perlakuan (*treatment*) seperti pengomposan, pemisahan limbah padat dan cair, serta pengolahan menjadi pelet pupuk. Biaya untuk solusi harus dapat menyeimbangkan biaya lainnya (misalnya biaya transportasi) atau harus

dapat meningkatkan pendapatan, dan pengguna harus dapat dilibatkan untuk mengetahui kualitas dan harga dari produk akhir.

Kesimpulan

Kami menyimpulkan bahwa ada banyak peluang untuk memanfaatkan limbah sapi perah di bidang pertanian, tetapi aplikasi limbah harus dilakukan dengan cara yang mudah, dapat diterapkan di banyak peternakan sapi perah, dan terjangkau bagi peternak. Terkait dengan solusi biaya, pengguna akhir harus terlibat dalam penyusunan solusi karena terkait kebutuhan spesifik terutama terhadap kualitas dan biaya dari produk akhir. Penelitian lebih lanjut harus fokus pada pengembangan sistem *collection*, *storage*, dan *treatment* yang murah bagi peternak dan koperasi sapi perah, juga memberikan Pendidikan terhadap peternak sapi perah dan pengguna. Lebih jauh, kemungkinan untuk memanfaatkan urine sapi perah, pemisahan *bioslury*, memperluas aplikasi dari sektor kehutanan, dan penelitian lapangan terkait aplikasi limbah pada tanaman kopi harus diteliti lebih lanjut. Strategi pengembangan sistem spasial untuk peternakan sapi perah di Jawa Barat perlu dilakukan, dengan menekankan penggunaan lahan bagi peternakan sapi perah sebagai salah satu kunci dalam peternakan sapi perah berkelanjutan.

Summary (English)

In West Java, Indonesia, most dairy farmers are currently discharging cattle manure into the environment. The excess of nutrients in ground and surface waters can cause pollution of local ecosystems, and can lead to contamination of drinking water sources. Utilizing cattle manure in other agricultural sectors can potentially reduce environmental pollution and local nuisance from discharged manure. This study explored barriers and opportunities for increased utilization of dairy cattle manure as a fertilizer or soil amendment in agricultural sectors in West Java Province in Indonesia. Interviews were conducted with various stakeholders, including 5 dairy cooperatives covering a large part of the dairy sector in West Java, representatives of various agricultural sectors (coffee, horticulture, and forestry), and provincial governments. In addition, a short literature review was conducted about the characteristics of agricultural sectors in West Java, and potential benefits and disadvantages of using cattle manure as a fertilizer or soil amendment.

Impacts of poor manure management
Representatives of dairy cooperatives estimated 60 to 90% of the manure from their member dairy farms was discharged. Dairy cooperatives unanimously indicated that local nuisance (i.e., annoyance of inhabitants about manure being deposited in their living environment) was a main issue, whereas fewer cooperatives mentioned pollution of surface waters, nature and rice fields as issues. Indicated pollution issues were region-specific, depending on the geographical location and local economic activities (proximity to rivers and tourism in Lembang, paddy production in Kuningan). This implies it is important to customize solutions to region-specific issues.

Potential benefits and disadvantages of using cattle manure as a fertilizer
The literature review showed that applying organic manures adds macro-nutrients (N,P,K) and micro-nutrients required for plant growth, and can have benefits for soil chemical and physical properties and soil biology. Macro-nutrients are also contained in chemical fertilizer, in a much more concentrated form than in manure. Stakeholders interviewed in this study emphasized that cattle manure is mainly valued for its effect on soil quality, particularly due to its organic matter contents. In the presented study it was calculated that for the situation in Pengalengan and Lembang an annual application of 30 ton/ha cow manure or 25 ton/ha chicken manure would be required to maintain the organic matter level of soils. This is in line with other recommendation rates for organic fertilizer for vegetable crops (20-30 tons per ha) but higher than average amounts applied in practice (13-17 tons/ha). Organic matter maintenance, however, seemed not a priority to farmers, as "improvement of soil productivity by cattle manure takes too much time, whereas fast results are needed to meet the growing demand". Total nutrient inputs based on recommended fertilizer rates were much higher than calculated crop requirements based on nutrient removal with harvested products. This suggests these recommended fertilizer rates are too high with regard to supply of (macro) nutrients, whereas recommended fertilization rates for organic manure were in line with our calculations for organic matter maintenance.

A main disadvantage of organic manures is that the nutrient content shows large variation and is often unknown. Insight in nutrient contents of organic manures is important, therefore, for the farmer to decide how much is needed and how much chemical fertilizer should be added to complement for each nutrient. The same holds for the uncertainty around the timing of release of nutrients from the organic matter. Manure can also pose risks of contamination of food or feed crops with unwanted biota, such as parasites and pathogens. Fresh, wet manure can damage horticultural crops when applied as mulch, but not when the manure is broadcasted and incorporated in the soil before planting.
Most agricultural sectors mainly use chicken manure (called 'postal' in Indonesian language) as organic fertilizer. Compared to cattle manure chicken manure generally has higher nutrient concentrations (including uric acid N which is more quickly available to plants), and has many practical advantages, including ease of obtaining, low transportation costs, and availability at all times. A

perceived advantage of cattle manure over chicken manure is that "cold (fermented) cattle manure does not burn crops".

Potential large-scale users in agriculture

Dairy cooperatives identified the following agricultural sectors as potential large-scale users of cattle manure: horticulture (3 cooperatives), tea (2), coffee (1), and forestry (1). Differences between cooperatives indicate that the type of large-scale user is area-specific, due to differences in agricultural commodities grown in those areas. Jointly the four agricultural sectors identified by dairy cooperatives occupy just over 900,000 ha in West Java (164,338 ha of vegetables and herbs (area of fruit unknown), 90,499 ha of tea, 47,082 ha of coffee, 602,532 ha forestry; only part of the forestry area can be used for manure application though). Assuming an application rate of organic fertilizer with the current practice of 18 tons/ha/year in coffee and tea, and 15 tons/ha/year in vegetables and herbs, theoretically about 5 Mtons of organic fertilizer could be applied on coffee, tea, vegetables and herbs. In case the recommended manure application rate of 20 t/ha/year would be used in vegetables, the amount of applied organic manure will be higher.

Stakeholder views of constraints to using cattle manure

According to dairy cooperatives a general constraint to utilize cattle manure on their own farm is the lack of land available for manure application, as well as the distance from cow barns to land. The disconnection of land and milk production leads to high transport and labour costs of manure and feed, and makes recycling of manure as a fertilizer extremely difficult. A second main constraint indicated by dairy cooperatives is the absence of a manure market and the lack of economic profitability of manure sales. According to some dairy cooperatives, there is a lack of formal agreements between dairy farms and crop farms, leading to uncertainties in supply, both for the supplier and buyer.

Interviewed large-scale users generally had a positive attitude towards using cattle manure. Constraints indicated by potential large-scale users were the (cost) price, manure quality, ease of handling, transport and application, and continuous availability of manure. This was in line with results of a recent survey among 320 horticultural farms in Lembang sub-district, which showed main issues are the difficulty to transport cattle manure, manure being often too wet and too costly to transport, manure being often not properly packed, and the difficulty of handling and applying cattle manure (Pronk et al., 2020). This implies the dairy sector needs to develop and implement improved manure management methods that enable easier handling, transport and application by end-users, and that ensure a continuous supply. The provincial government indicated waste management cannot be enforced to small-scale farmers, and emphasized the lack of awareness from dairy farmers as a constraint.

Stakeholder views of opportunities for using cattle manure

As opportunities for using cattle manure, stakeholders mentioned: (i) socialization and education of dairy farmers and potential end-users, (ii) various technical solutions for collection, storage, treatment (drying), and transport of manure, and (iii) formal agreements between supplier and end-users. Proposed technical solutions were mainly related to the drying of the wet cattle faeces, which should lead to easier handling and transport of manure, including methods for collection (communal piping system, picking up manure from farms), storage (communal storage), and treatment (composting, manure separation, and processing into pelletized fertilizer). Costs of technical solutions will have to be balanced against a foreseen reduction in other (e.g. transport) costs or increased revenues, and the end-user should be involved to know requirements on the quality and price of the end product.

Conclusion

We concluded that there are opportunities for utilization of dairy cattle manure in agricultural sectors, but this requires an easy, reliable, and affordable delivery system by the dairy sector. Due to costs of solutions, the end-user should be closely involved in the development of solutions to specify requirements on the quality and cost price of the end-product. Future activities should focus on development of affordable manure collection, storage, and treatment methods in dairy cooperatives, as well as education of dairy farmers and potential end-users. Furthermore, possibilities to utilize urine from dairy farms, separation techniques for bio-slurry, expanding cattle manure application in the forestry area, and field research on manure application in coffee should be explored. Parallel to technical solutions to solve the issue of manure discharging, a spatial development strategy is needed for the dairy sector in West Java, with land-based dairy farming being key to sustainable development.

1 Introduction

The demand for milk increases in Indonesia due to population growth, higher middle-class incomes, and increased awareness of the importance of milk as part of a healthy diet (Marangoni et al., 2019; Pereira, 2014). In addition, the Indonesian Government aims to strongly increase domestic dairy production, in order to increase self-sufficiency. While most of the domestic milk production takes place on small-scale dairy farms, the increase in demand may offer opportunities for small-scale farmers to increase milk production, and improve incomes and livelihoods. On the other hand, the dairy sector is already putting significant pressure on different aspects of the environment, including animal manure causing pollution of ground and surface waters. Increases in milk production may further increase environmental pressures, particularly when the increase in production is realized by increasing the number of dairy cattle (Government strategy; Kementrian Pertanian, 2015) leading to higher manure production from farms.

Most of the dairy production in Indonesia takes place on small-scale dairy farms on Java, with West Java Province being the second-largest producer in Indonesia. In this province herds consist of 3 to 5 dairy cows, housed in tie-stalls with no access to grazing. Due to the scarcity of land on Java, most dairy farms have only a small amount of land (21 livestock units per ha; De Vries and Wouters, 2017) for forage production, leading to challenges of supplying sufficient and good quality forage to the dairy herd, and recycling cattle manure as a fertilizer. Most of the dairy farms, therefore, are discharging part of the manure into the environment (De Vries and Wouters, 2017). Some farmers utilize manure by applying manure to land for forage production close to barns, but this practice often leads to over-fertilization because large amounts of manure are concentrated on small parts of land (De Vries et al., 2020).

Nutrients leaching from discharged manure and nutrients leaching and run-off from fields can cause eutrophication, which occurs as a response to the excess nutrients in water surfaces, including nitrogen (N) and phosphorous (P) from livestock manures (Biagini & Lazzaroni, 2018; WHO 2016). The discharged manure can also lead to contamination of drinking water sources due to the leaching of nitrate (NO_3^-) (WHO, 2016), and to soil acidification due to ammonia emission (NH_3). Present discharged manure ends up in local streams and rivers, including the Citarum river flowing through West Java, which is one of the world's most polluted rivers due to industry-, household-, and livestock waste (Water and sanitation program: technical paper, 2013). Recently it was estimated that the dairy population in the Lembang region, West Java contributes 2.5% to the total N pollution of the Citarum river (Zahra, W.A., et al. 2021). Besides environmental pollution, the discharging of manure is causing local nuisance (i.e., annoyance of inhabitants about manure being deposited in their living environment).

At the national level there are several policies and programs that should enhance manure management on dairy farms and lead to reduction of manure discharging. The Indonesian Government initiated a seven-year program for cleaning the Citarum river (Bappenas, 2020), in which the Government stimulates livestock farmers to stop discharging manure. In addition, according to the regulation of the Ministry of Agriculture no. 100 (2014), it is mandatory for the livestock sectors to have storage and perform manure management. In line with this policy, according to the regulation of the Ministry of Environment no. 11 (2009), livestock sectors should manage manure in order not to exceed the maximum limit of wastewater management. Greenhouse gas mitigation strategies as laid down in Indonesia's National Determined Contribution (NDC) does not directly relate to use of cattle manure as a fertilizer, but only to the use of manure for biogas production (Direktorat Jendral Perubahan Iklim, 2017).

Although dairy farmers acknowledge that discharging manure into the environment is a problem, utilizing the manure is hampered due to various reasons, most importantly because of limited land to apply cattle manure on their own land and a lack of possibilities to sell the manure ("lack of manure market"; De Vries and Wouters, 2017). Utilizing cattle manure in other agricultural sectors can potentially reduce discharged manure and related environmental pollution and local nuisance. So far, however, possibilities for increased utilization of dairy cattle manure as a fertilizer in other agricultural sectors in West Java have not been explored.

1.1 Objective

The objective of this study was to gain insight in barriers and opportunities for increased utilization of dairy cattle manure in agricultural sectors in West Java Province in Indonesia. To this end, a literature review was conducted to describe characteristics of potential large-scale users and the value of cattle manure as a fertilizer and soil amendment, and interviews were conducted with dairy cooperatives in West Java, potential large-scale users, and policy makers.

2 Materials and methods

2.1 Literature review

A short literature review was conducted to describe characteristics of agricultural sectors in West Java Province, and composition and theoretical value of cattle manure as a fertilizer (nutrient contents) and soil amendment (mainly organic matter contribution).

2.2 Selection of stakeholders

Three types of stakeholders were approached in this study related to manure management in the region of West Java: i) dairy cooperatives in West Java, ii) potential large-scale users, and iii) policy makers. The dairy cooperatives in West Java were considered to be key informants as most dairy farmers in West Java are members of a dairy cooperative. Potential large-scale users were identified via dairy cooperatives, after which they were approached for an interview ('snowball sampling').

Dairy cooperatives
Dairy cooperatives in West Java are united in the Union of Dairy Cooperatives (GKSI). The head of GKSI was asked to select 5 of the present 14 dairy cooperatives in West Java (Table 1). The selection was greatly based on the cooperatives willingness to participate in the research.

The dairy cooperatives in this study covered 9,880 dairy farmers (Table 1). Compared the total number of dairy cattle populations in West Java province (i.e., 120,179 head; (Livestock statistic, 2019)), the dairy cooperatives covered about 25-41% of dairy cattle population in West Java province (assuming an average herd size of 3-5 heads per dairy farm in the selected dairy cooperatives; USDA, 2019).

Table 1 *List of selected dairy cooperatives.*

Location	Dairy cooperative	Role of interviewees	No. of active members
Bandung Barat regency	KPSBU	Managing director	4,500
Garut	KPGS	Board member	1,290
Kuningan	KSU Karya Nugraha	Secretary	1,100
Sumedang	KSU Tandang Sari	Secretary	790
Bandung regency	KPS Pengalengan	Managing director	2,200

Large-scale users
Based on the interviews with dairy cooperatives, three large users were identified for further in-depth interviews about opportunities of utilizing cattle manure as a fertilizer in agriculture in West Java Province: coffee, tea, forestry, and horticulture. Three key respondents from these sectors were interviewed (Table 2):

- A group leader of a coffee farmer group (i.e., Kelompok Tani Rahayu) located in Pengalengan sub-district, Bandung Regency, consisting of 211 members. Each group member has approximately 1-2 ha of coffee plantation numbering to a total of 350 ha.
- A large crop farmer in Pengalengan, Bandung Regency, cultivating potatoes, cabbages, and carrots on 50 ha of land.
- A director assistant of the forestry area KPH North Bandung, which has a formal agreement with the dairy cooperative KPSBU in Lembang allowing member dairy farmers to use 165 ha of forest area where farmers can cultivate forage underneath the trees, including the possibility of manure application in the forest area.

Table 2 *List of large-scale users.*

Location	Large-scale user	Role of interviewees
Bandung regency	Coffee plantation	Group leader of 211 small-scale coffee farmers
Bandung regency	Horticulture plantation	Owner of a large horticultural farm (potatoes, cabbage, carrot)
Lembang	Forestry plantation	Director assistant

Policy makers
Issues, regulations, and programs related to manure management on dairy farms were discussed with two representatives of provincial governments:

- the head of department of production of Food Security and Livestock Services of West Java Province;
- the head of department for water and air pollution of the Environmental services of West Java province.

2.3 Data collection

Interviews with representatives of dairy cooperatives, potential large-scale users, and policy makers were conducted between November 2020 and January 2021. The interview was held by phone, lasted for 30-45 minutes, and was recorded for which consent was granted by the interviewee.

Interviews were aimed at:

1. Describing the current situation of dairy cow manure management (dairy cooperatives) or organic fertilizer utilization (large-scale users) in West Java, including description of current initiatives for utilization of cattle manure.
2. Identifying constraints and potential opportunities for large scale utilization of manure from dairy farms.

The interview included questions related to the description and issues of current manure management, potential improvements for manure management, constraints in improving manure management, and possibilities to overcome these constraints.

3 Results

3.1 Description of agricultural sectors in West Java

3.1.1 Dairy sector

An estimated 99% of domestic milk production in Indonesia takes place on Java, where dairy processors are located. Most dairy farms in Indonesia are smallholder dairy farms, covering about 90% of the national dairy herd and contributing to about 77% of domestic fresh milk production (USDA and GAIN, 2019). Small-scale dairy farmers typically keep 3-5 dairy cows with a milk production below 10 liters of milk per day (USDA and GAIN, 2019)). In small-scale dairy farms, cows are housed in tie-stalls with no access to grazing (‘zero-grazing’). Most farms own or rent only a small amount of land for production of fodder or food crops, and part of the dairy farms are landless (e.g., 16% of dairy farms in Lembang district; De Vries and Wouters, 2017). The scarcity of land for forage production leads to challenges of supplying sufficient and good quality forage to the dairy herd, and recycling cattle manure as a fertilizer.

West Java Province has, with an annual milk production of 351,885 Tons of milk, the second largest milk production on Java which is 35% of the national milk production (Livestock Statistic, 2019). The dairy cattle population in this province accounted for 120,719 heads, equalling 22% of the national dairy cattle population (Livestock Statistic, 2019). From 2015 to 2019, milk production in Indonesia increased (Figure 3.1). In West Java, milk production increased by 28%, whereas the dairy cattle population increased by 3.3% (Livestock Statistic, 2019). Most dairy farms in West Java province are located in the high lands (>1,000 m above sea level). The establishment of dairy farms in West Java Province's high lands is related to the climatic conditions (i.e., temperature ranges from 15-24°C and humidity ranges from 56-90%) suitable for raising dairy cattle.

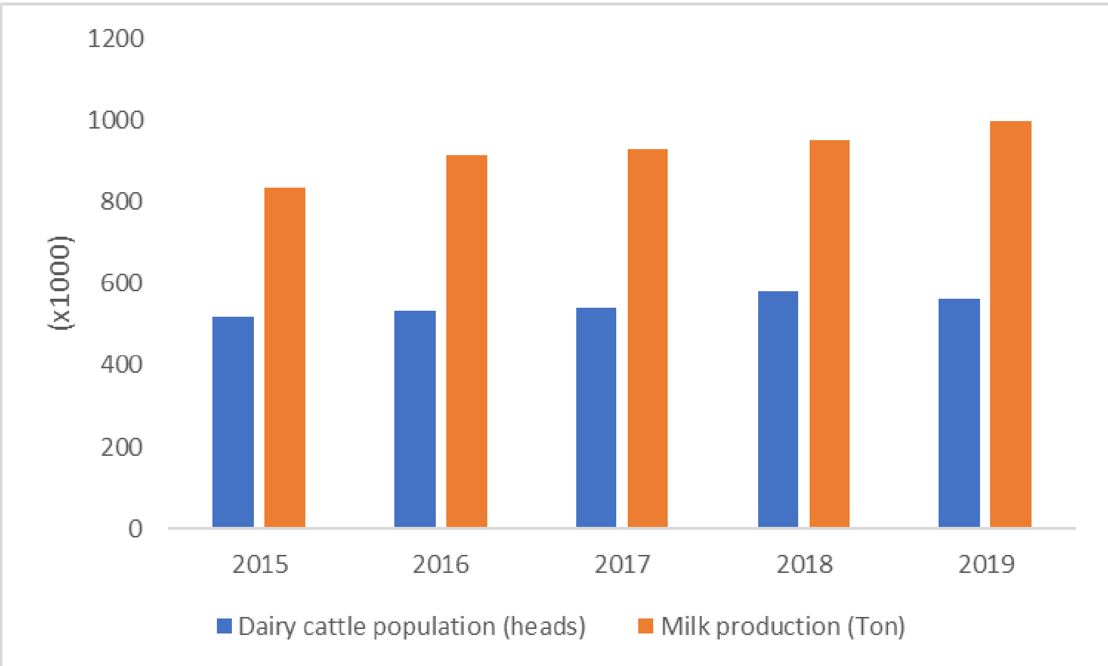

Figure 3.1 *Milk production and dairy cattle population in Indonesia (2015-2019); (Livestock Statistic, 2019).*

Characteristics of dairy cattle manure

Different terms are used for the various types and forms of cattle excreta. In this report we use the following definitions (de Vries and Wouters, 2017):

- Urine: the pale-yellow fluid stored in the urinary bladder and excreted by urination. Urine typically contains less than 4% dry matter and the larger part of total excreted nitrogen and potassium salts.
- Faeces (or 'dung'): the solid or semisolid remains of the food that could not be digested in the small intestine and discharged through the anus by defecation. Faeces typically contain 12-15% dry matter, and the larger part of total excreted phosphorus and organic matter.
- Manure: general term for faeces, either with (e.g., slurry) or without urine (e.g., cow pies). The dry matter content may vary.
- Slurry: liquid mixture of faeces and urine. Slurry typically contains 5-10% dry matter.
- Solid manure: stackable manure, obtained by solid-liquid separation of faeces and urine, and/or drying of the separated solids. Solid manure typically contains more than 20% dry matter.
- Digestate (or 'bio-slurry'): the liquid by-product from biogas production (or 'anaerobic[1] digestion'). Digestate typically contains less than 10% dry matter. All the nutrients in the input slurry (N, P, K, etc.) remain in the digestate. The biogas contains digested carbohydrates (mainly gaseous methane CH_4 and carbon dioxide CO_2). Biogas can be highly toxic to humans and animals because of the presence of small quantities of gaseous hydrogen sulfite (H_2S), depending on the sulphur levels in feed ingredients.
- Compost: a concentrated, stabilized soil improver made from solid manure and additives, typically containing more than 60% dry matter in the finished compost. Compost is obtained through a bio-thermal aerobic[2] treatment of manure and additives, which is autonomous temperature increase due to bacterial activity, accompanied by a reduction in moisture due to release of water vapor and a reduction in the numbers of pathogens. Nitrogen loss during composting varies between 20 and 60%.

The chemical composition of manures varies greatly between animal types, as well as in between manure types (Table 3). The chemical composition of manure is influenced by the entire manure production chain that can be defines as crop-feed-animal-excreta-storage-field chain (Sommer et al., 2013). Table 3 shows the macro-nutrient composition of different types of cattle manure in West Java, and of "postal" (local term) which is a mixture of chicken manure and rice husks (bedding) from broiler farms. Postal, the mixture of chicken manure and rice husks, is frequently used as fertilizer in agriculture in West Java. From the data in table 3 the following overall conclusions can be drawn:

- Fresh cattle faeces, slurry, and bio-slurry are relatively low in dry matter content (i.e., a wet product), resulting in relatively low in nutrient contents, less stackable, and more difficult to handle and transport.
- When cattle faeces are stored on a manure heap or composted, the dry matter content increases (i.e., a dryer product), as well as its nutrient contents (although nutrient loss is significant during composting).
- Chicken manure has a relatively high dry matter content, with relatively higher nutrient contents (particularly total and mineral nitrogen).

[1] Anaerobic: without air supply (hence, without oxygen).
[2] Aerobic: with air supply (hence, with oxygen).

Table 3 *Chemical composition of different types of cattle manure and 'postal' (mixture of chicken manure and rice husks), expressed on a wet basis (in kg/100 kg fresh product).*

	Dry matter (%)	N-total (%)	P (%)	K (%)	N-min (%)	C/N ratio	Source
Cattle manure:							
Fresh faeces	14.9	0.3	0.1	0.1	0.03	-	De Vries et al., 2020
	14.9	0.5	0.1	-	0.10	10	Sefeedpari, et al., 2020
	18.2	0.3	0.1	-	0.20	-	Zahra W.A., et al., 2021[2]
Manure heap	39.3	0.7	0.2	0.3	0.03	-	De Vries et al., 2020
Compost[1]	42.5	0.8	0.3	0.4	0.03	-	De Vries et al., 2020
	49.2	1.6	0.5	-	0.09	9	Sefeedpari et al., 2020
Bio-slurry	3.3	0.1	0.003	-	0.05	-	Zahra W.A., et al., 2021
Chicken manure:							
Postal	85.0	3.2	0.4	-	0.21	9	Sefeedpari et al., 2020[3]
	41.2	0.6	0.5	0.6	-	9	Van den Brink et al., 2015[4]
	73.7	1.5	0.5	1.2	-	8	Van den Brink et al., 2015[4]
	79.8	2.9	1.0	2.1	-	10	Van den Brink et al., 2016[4]
	62.5	1.4	1.4	1.6	-	11	Van den Brink et al., 2016[4]
	70.9	1.6	1.5	1.6	-	14	Van den Brink et al., 2016[4]
	57.7	1.4	1.8	1.5	-	12	Van den Brink et al., 2016[4]

[1] Compost in the study of Sefeedpari et al. consists of cattle manure mixed with postal, causing relatively high dry matter (DM) and nutrient contents.
[2] Fresh faeces dried for 20 days.
[3] In the study by Sefeedpari et al. (2020) postal is defined as broiler manure mixed with bedding material
[4] In the studies by Van den Brink et al. (2015 and 2016), postal is defined as chicken manure

Given a dairy cattle population in West Java of 120,719 heads (Livestock Statistic, 2019) and assuming N excretion in dairy cattle manure was 197 g N/day and P excretion was 56 g P/day (Zahra W.A., et al., 2020), an estimated amount of 23.8 ton N/day (8,687 ton annually) and of 6.8 ton P/day (2,482 ton annually) are excreted by dairy cows in West Java province. This annual amount of N produced by dairy cattle is equivalent to 18,885 tons of urea fertilizer.

3.1.2 Plantation, forestry, and horticultural sectors

Agriculture plays an important role in the Indonesian economy. In 2019, agriculture contributed to 12.7% of the total national GDP. In interviews with dairy cooperatives, the following agricultural sectors were identified as potential large-scale users of cattle manure (see paragraph 3.2): coffee plantations, tea plantations, horticultural sector, and forestry areas. The plantation sub-sector is about 26 % and the horticulture sector 14% of the agriculture GDP (BPS, 2019). Also in terms of land use, the plantation and horticulture are large sectors. In the following paragraphs characteristics of these sectors and their fertilizer requirements are described.

3.1.2.1 Coffee plantation

Coffee plantation is one of the most important commodities in Indonesia, occupying 1.2 million ha. In West Java province, coffee plantation is the fourth largest land user of the total plantation area after coconut, tea, and rubber (Table 5). In 2019, Indonesia produced 0.7 Mton coffee annually and was the number four coffee producer in the world. About 48% of coffee production in Indonesia was exported, with the US as the main destination country (16%), followed by Malaysia (10%), Italy (10%), Egypt (10%), and Japan (7%). The export value of coffee is significant, i.e., 883,12 million USD in 2019 (Coffee Statistic, 2019). In Indonesia, the national coffee consumption increases annually. Over the last five years (2015-2019), coffee consumption increased by 8%, and it is predicted to continue to increase. The growing demand for coffee is linked to the younger generation switching over from tea to coffee and a newfound appreciation for locally produced coffee (Hirschmann, 2021).

Table 4 *Distribution of plantation production in West Java (source: West Java in Figure (2019)).*

Products	Area (ha)	Production (ton)
Coconut	147,283	92,060
Tea	90,499	99,761
Rubber	57,504	32,715
Coffee	47,082	21,375
Oil palm	37,198	210,952

Java is the island with the second highest coffee production in Indonesia, after Sumatra. In 2019, West Java province was the 10th largest coffee producer in Indonesia (Production 21,375 ton; 47,082 ha) of all provinces in Indonesia. Although, being ranked number 10 in terms of coffee production, the coffee productivity in West Java is ranked number 3 at the national level with 808 kg/ha (Coffee statistic, 2019). Pengalengan is known as one of the largest coffee producers in West Java Province, with a total area of 10,027 ha and a production of 6,906 ton of processed coffee (Bandung Regency in Figure, 2018). Depending on the coffee plantation scale, three different coffee plantation typologies can be distinguished: Private enterprise, Smallholder enterprise, and Government enterprise. The smallholder enterprise dominates, accounting for 98% of the total production (0.68 Mton; 1.17 million ha). Due to the high demand for coffee, coffee production is expected to increase. Sustainability has become a paramount concern in the coffee industry over the past several years (Byrareddy et al., 2019). Hence, sustainable increase of coffee production is essential for coffee producers.

Fertilizer requirements
A coffee plant requires sufficient levels of mineral nutrients such as nitrogen (N), phosphorus (P), and potassium (K) in the soil. Coffee plantations use both organic and artificial fertilizer. A study by Byrareddy et al., (2019; case study in Sumatra island), for example, indicated that current sources of fertilizer used are NPK and organic fertilizer (i.e., compost). The compost was made from animal manure and dried leaves, and branch cuttings. In a study by Rusli et al., (2015), on Robusta coffee, urea, SP 36, and KCL were used as artificial fertilizer.

Recommended fertilizer rates depend on the soil type and age of the plants. The general recommendation for organic fertilizer is 20 kg/plant/year (Direktorat Jendral Perkebunan, 2014), i.e., 50 ton/ha/y in case of 2,500 plants per hectare. According to Direktorat Jendral Perkebunan (2014), the application of organic fertilizer is important for soil organic matter. Table 6 shows the general recommendation of artificial fertilizer for coffee plantation.

Table 5 *General recommendation of artificial fertilizer for coffee plantation (Source: Directorate general of plantations; Good Agriculture Practices for coffee, 2014) with calculated rates per nutrient in kg/ha with 2,500 plants per hectare.*

Age (year)	Urea (46% N)	SP 36 (36% P_2O_5)	KCL (60% K_2O)	N	P_2O_5	K_2O
		(g/plant/year)			(kg/ha/year with 2,500 pl/ha)	
1	40	50	30	45	45	45
2	100	80	80	115	72	120
3	150	100	100	173	90	150
4	200	100	140	230	90	210
5-10	300	160	200	345	144	300
>10	400	200	250	460	180	375

3.1.2.2 Forestry

The total forest land in West Java province is 602,532 ha or 17% of the total area of West Java province (Perhutani, 2021). Based on its function, the forest area is classified into forest production area (36%), limited forest production (29%), and protection and conservation area (35%). The pine tree is the major planted tree in the forest area (49%), followed by teak (28%), mahogany (9%), acacia (7%), rubber (5%) and eucalypt (1%). Figure 3.2 shows the distribution of forest management area (KPH: Kesatuan Pemangkuan Hutan) North Bandung, West Java. The dairy cooperative of Lembang (KPSBU) is located in the KPH of North Bandung. Table 7 shows the KPH in West Java province in which the dairy cooperative is located. The KPH Garut has the largest forest area, followed by Bandung regency, Sumedang, Kuningan and Bandung North.

Table 6 *The forest area management in West Java province in which dairy cooperative located. (Source : Perhutani 2021)*

Dairy farms location	**Forest area management (KPH)**	**Total area (ha)**
West Bandung regency	Bandung North	20,560
Garut	Garut	81,510
Kuningan	Kuningan	25,644
Sumedang	Sumedang	36,547
Bandung regency	Bandung South	55,476

Horticulture

Horticulture plays an important role in the Indonesian economy structure. The total production of horticulture products (i.e., vegetables, fruits, and herbs) reached 38 million tons in 2019. The majority of horticulture production takes place on Java (57%), followed by Sumatra (25%), Bali and Nusa Tenggara (7%), Sulawesi (6%), Kalimantan (4%), and Maluku and Papua (1%). About 44% of horticulture production (in terms of volumes) on Java takes place in East Java, followed by West Java with 26% and in Central Java, Banten, the special region Yogyakarta and the special region Jakarta 30% of the production takes place (Horticulture statistic, 2019).

Over more than 55 horticulture products (i.e., herbs, fruits, and vegetables) are grown in West Java. The total area of vegetables and herbs is 164,338 ha. Table 8 shows the main horticulture crops produced in West Java province ranked on their production. Ginger is the main herb, tomato is the main vegetable and banana is the main fruit being produced in West Java.

Table 7 *Main horticulture products in West Java (source: Horticulture statistic, 2019).*

Products	**Commodity**	**Production (ton)**
Herbs	Ginger	34,078
Vegetable	Tomato	284,948
	Chilli	263,949
	Cabbage	275,419
	Potato	245,418
	Chinese Cabbage	179,925
Fruits	Banana	1,220,174
	Mango	418,522
	Pineapple	228,601

Potato and cabbage

Potato production in Indonesia reached 1.28 million ton in 2018. Most of the production (83.5%) was found in Java island. West Java is the third largest potato producer in Indonesia with an acreage of 12,218 ha and a production of 265,537 ton equal to 20.5% of the national production (Horticulture statistic, 2018).

Cabbage production in Indonesia reached 1.41 million ton in 2018. Most of the production (82.2%) was found on the island of Java. West Java province is the second largest cabbage production in

Indonesia. The total cabbage production in West Java province was 12,333 ha with a production of 280,449 ton equal to 20% of the national production (Horticulture statistic, 2018).

Table 8 *Main horticulture products in Pengalengan (source: The district of Pengalengan in figures 2019).*

Products	Areas (Ha)	Production (ton)
Potato	2,943	614,340
Cabbage	2,734	631,962
Chilli	542	119,329
Onion	794	98,448
Carrot	1,705	328,199

Fertilizer requirements
A simple method to determine how much the crop requirements are for nutrients is to calculate the nutrient removal with harvested products. With this method the average nutrient content of a marketable crop part is multiplied with the yield (table 10). Average nutrient content of crops used to calculate the nutrient removal were taken from the nutrient data base of the USDA Crop Nutrient Tool (https://plants.sc.egov.usda.gov/).

With a cabbage production of 20 t/ha about 23 kg nitrogen, 6 kg P_2O_5 and 28 kg K_2O is removed from the field. With fertilizers, either chemical or organic, this is the minimum amount of nutrients that should be applied to maintain soil fertility. For an optimal nutrient uptake by the crop additional fertilizer quantities are required to compensate for losses of nutrients

Table 9 *Nutrient removal with harvested product (source: USDA Crop Nutrient Tool[1]).*

	Est. yield kg/ha	N	P_2O_5	K_2O
Cabbage, for head (without outer leaves)	20,000	50	14	62
Lettuce-Chrisphead or Iceberg	10,000	13	7	12
Onion-Green (bulb)	15,000	32	14	22
Pepper-Chili (red)	5,000	16	5	25
Potato-Irish for tuber	20,000	66	23	98
Tomato	30,000	45	21	94

[1] https://plants.sc.egov.usda.gov/

For potato production, the recommendation rate of organic fertilizers is 20-30 t/ha cattle, goat or chicken manure and 20 t/ha rice straw compost. The recommendation rate for inorganic fertilizers is: TSP (46% P_2O_5) 250-300 kg/ha, Urea (46% N) 200-300 kg/ha, Ammonium sulphate (21% N) 300-400 kg/ha, and KCL (60% K_2O) 200-300 kg/ha (Setiawati et al., 2007).

For cabbage production, the recommendation rate of organic fertilizers is 30 t/ha cattle manure or 20 t/ha goat manure or 18 t/ha rice straw compost. The recommendation rate for inorganic fertilizers is: TSP (46% P_2O_5) 250 kg/ha, Urea (46% N) 100 kg/ha, Ammonium sulphate (21% N) 250 kg/ha, and KCL (60% K_2O) 200 kg/ha (Setiawati et al., 2007).

We calculated the nutrient input by multiplying the recommended fertilizer rates above with the fertilizer content (results shown in Table 11). For manure an estimate was made based on the data for cattle manure presented in Table 3. No information about rice straw compost is known and therefore not filled in the table. Based on these recommendations, the calculated amount of nitrogen that should be applied in potato is 314 kg/ha. From the total nitrogen applied with cattle manure about half will be available for the first season which will be around 60 kg/ha. When considering also an estimated mineralization of nitrogen of 50 kg/ha from the soil organic matter a total of about 300 kg nitrogen is available for the potato crop. When these amounts are compared to the nutrient removal with harvested crops it seems that even when additional fertilizers are needed to compensate for losses this is much higher than what is removed from the field (Table 11).

Table 10 *Nutrient input with recommended fertilizers and rates by Setiawati et al. (2007).*

	Potato				Cabbage			
	Quantity kg/ha				Quantity Kg/ha			
Product	applied	N	P_2O_5	K_2O	applied	N	P_2O_5	K_2O
Manure (cattle)	25,000	125	50	63	30,000	150	60	75
rice straw compost	20,000	?	?	?	18,000	?	?	?
TSP	275	0	127	0	250	0	115	0
Urea	250	115	0	0	100	46	0	0
AS	350	74	0	0	250	53	0	0
KCL	250	0	0	150	200	0	0	120
Total		314	177	213		249	175	195

3.1.3 Soil fertility in Bandung region

A background on soil fertility near Lembang and Pengalengan is explained, as these are important areas for horticulture, coffee and tea plantations, as well as for dairy production. Just south of Bandung Pengalengan is situated, favourable for production of horticultural crops such as cabbage, carrots, tomatoes and potatoes. Besides many tea plantations and coffee plantations can be found here. The area is mountainous, and crops are grown at an altitude of 1000 to 1600 m above sea level (ASL). North of Bandung another important horticulture area is situated around the city of Lembang which is also at 1000 to 1600 m ASL. The dominant soil type where horticulture takes place is Andosols (volcanic parent material) for both locations (Soilsgrids.org; Devnita et al., 2010).

Usually, fertility of those soils is quite high, but pH of those soils can be low causing limited uptake of some nutrients by crops. P retention of andosol sampled near the volcano Tanguban Perahu (Lembang) was high as a result of this (Devnita et al., 2010). The topsoils showed 96 to almost 100% P retention. In many cases the P content of those soils is high but are not available to plants Komiyama et al., 2014). On average pH-KCL of the soils are low with values ranging from 3.3 to 5.5 (Table 4). For an optimal nutrient uptake, a pH-KCl level between 5.5 and 6.5 is considered optimal and liming is therefore recommended to increase pH and optimize fertilizer use (Von Uexkull, 1986; Brust, 2019). Also, for soil life involved in decomposing organic matter a pH between 6 and 8 is considered as optimal (Miller and Donahue, 1995). The C-org percentage is on average high for both regions (Table 4). The C/N ratio is low indicating that the organic matter contains more nitrogen than carbon and because of the decomposing process significant amounts of nitrogen will be available for plant growth. Estimated is that between 50 to 100 kg/ha nitrogen is mineralized from the organic matter annually.

Table 11 *Status of soils in Pengalengan and Lembang region.*

Region	Description	pH - KCl	pH-H2O	C-org (%)	N-total (%)	C/N ratio	source
Pengalengan	top soil 0-20 cm	5.0	6.0	3.9	0.3	13	Djuniwati and Pulunggono, 2009
Pengalengan	top soil 0-20 cm	4.9			0.7		Van den Brink et al., 2015
Pengalengan	top soil 0-20 cm	4.9		4.7	0.5	9	Van den Brink et al., 2016
Pengalengan	top soil 0-20 cm	4.4		5.8	0.6	9	Van den Brink et al., 2016
Pengalengan	horizon Bw	5.2	5.6	7.4			Rahayo and Van Renst, n.y.
Pengalengan	horizon 2A2	5.3	5.6	12.5			Rahayo and Van Renst, n.y.
Pengalengan	horizon 2Bw1	5.5	5.6	9.4			Rahayo and Van Renst, n.y.
Lembang	Volcanic Ash soil (A horizon)		4.5	5.7	0.6	9	Yatnoa and Zauyah, 2008
Lembang	Volcanic Ash soil (B horizon)		4.7	3.2	0.3	11	Yatnoa and Zauyah, 2008
Lembang	Volcanic Tuff soil (A horizon)		4.5	2.6	0.3	8	Yatnoa and Zauyah, 2008
Lembang	Volcanic Tuff soil (B horizon)		5.0	1.3	0.2	8	Yatnoa and Zauyah, 2008
Lembang	Cisarua horizon A2	5.1	5.2	8.1			Rahayo and Van Renst, n.y.
Lembang	Cisarua horizon Bw	5.2	4.7	2.8			Rahayo and Van Renst, n.y.
Lembang	Cikole horizon A2	5.2	5.3	10.2			Rahayo and Van Renst, n.y.
Lembang	Cikole horizon Bw2	5.6	5.3	3.8			Rahayo and Van Renst, n.y.
Lembang	Cikole horizon 2A	4.8	5.3	15.1			Rahayo and Van Renst, n.y.
Lembang	top soil 0-20 cm	4.2	4.4	2.5	0.3	9	Own data, 2020
Lembang	top soil 0-20 cm	4.3	4.7	1.8	0.3	6	Own data, 2020
Lembang	top soil 0-20 cm	4.2	4.7	6.6	0.7	9	Own data, 2020
Lembang	top soil 0-20 cm	4.3	4.7	6.0	0.6	10	Own data, 2020
Lembang	top soil 0-20 cm	3.3	3.9	8.7	0.8	12	Own data, 2020
Lembang	top soil 0-20 cm	4.9	5.4	3.0	0.4	9	Own data, 2020

3.1.4 Macro-nutrients

Organic manure is a direct source of nutrients which can reduce the need for chemical fertilizer. In many cases the value of organic manure is only considered for the main elements N, P and K, but in terms of trace elements it can also contribute to a fertile soil. Nevertheless, to meet the crop nutrient requirement for N, P and K large volumes of manure are needed because of the relatively low nutrient concentration in manures compared to chemical fertilizer. In case of potato roughly 250 kg nitrogen per ha is needed for an optimal nutrient uptake by the crop. With a cow manure nitrogen content of maximum 1% of the applied product this implies that, when assuming all nitrogen will become available during the crop cycle, at least 25 t/ha of cow manure needs to be applied. However, not all nitrogen will be mineralized during one crop cycle. Based on mineralization rate a farmer can decide to add more but needs to realize that with this phosphorus levels may easily be exceeded. With applying 25 t/ha manure a total of about 100 to 125 kg P_2O_5 and 100 to 125 kg K_2O will be applied as well. In many situations the potassium requirement of vegetable crops is comparable or especially for fruiting crops significantly higher than the nitrogen requirement. Next to macro nutrients organic manure can supply trace elements that otherwise would not be applied with inorganic fertilizers (Naeem et al., 2020; Chaudhary and Narwal, 2005).

Compared to cow manure, total N and mineral N is higher in postal: on average total N was 0.5% in dairy manures, and 1.8% in postal (Table 3; in line with other literature, e.g., Jensen, 2013), implying more than 3 times less weight needs to be handled and transported in case of postal. However, when looking at the ratios for cow manure and chicken manure differences are present. For chicken manure the ratio for N:P:K is approximate 1:1:1 while for cow manure this is 1:0.5:0.5 (Table 3; in line with e.g. Jensen, 2013). In vegetables P requirements are lower than N requirements, thus with chicken manure the risk of exceeding P supply is higher than with cow manure when considering a same N requirement. For K the content in cow manure is lower than in chicken manure but in vegetable production this nutrient is required at similar or higher levels of N. When using cow manure, it is therefore needed to use chemical fertilizer to complement the K requirement.

An issue with organic fertilizer is that the nutrient content shows large variation and is often unknown, whereas the farmer has to know the exact nutrient content of the manure to decide how much is needed and how much chemical fertilizer should be added to complement for each nutrient.
Another issue (for both cow and chicken manure) is that the timing of release of nutrients from the organic matter is uncertain. Most likely soil temperature and moisture content conditions are optimal to have a fast mineralization process in Pengalengan and Lembang. However, the pH is a bit low for optimal soil life processes. Uptake curves for most vegetables are as such that during the first couple of weeks after planting not that many nutrients are needed. During the period of fast growth maximum uptake per day is present while at the end of the crop less nutrients are needed again. In case nutrients from manure are not available during the period of fast growth, crop yield might be reduced. In case towards the end of the crop cycle a lot of mineralization takes place too many nutrients are present, and risk of leaching is present.

3.2 Potential benefits and disadvantages of using cattle manure in horticulture

The fertilizer value of manure is related to its chemical composition, especially to the contents of macro-nutrients nitrogen (N), phosphorus (P) and potassium (K), but also to micro-nutrients such as Fe, Mn, B, Zn and Cu, which are essential for plant growth. In addition, applying organic manures on soils can improve other soil chemical properties (soil organic matter, CEC, and pH), soil biology (microbial and faunal activity), and soil physical properties (e.g., bulk density, infiltration rate and water-holding capacity; Rayne and Aula, 2020). Manure, and the other hand, can also pose risks of contamination of food or feed crops with unwanted biota or abiota, such as parasites, pathogens or heavy metals.

3.2.1 Organic matter

The presence of soil organic matter and use of organic manure in agriculture has many benefits (Miller and Donahue, 1995; Rayne and Aula, 2020; Brust, 2019; Sorensen et al., 2019). However, one can only expect positive aspects when significant quantities are applied over a long year period (Darwish et al., 1995).

In the first-place organic manure contributes to the organic matter of the soil. Organic matter is able to supply gradually a significant quantity of nitrogen, phosphorus, and sulphur. Nutrient and water holding capacity increase and soil structure improves. Also organic matter stimulates the presence of soil life that can be beneficial for crop growth. Use of organic manure might also influence soil acidity. However, effects are not consequent as some studies indicate an increasing pH of the soil increases whereas others indicate a decrease in soil pH.

Based on the organic matter situation in Pengalengan and Lembang an annual application of 30 ton/ha cow manure or 25 ton/ha chicken manure is required to maintain the organic matter (see Box). For a well-balanced fertilization schedule a farmer should consider the nutrients supplied with this amount.

Example calculation of needed organic manure to maintain soil organic matter

A soil contains 2% organic C; soil bulk density is 1.4 kg/dm3. How much organic matter is required to maintain soil organic matter in the 0-20 cm topsoil? The organic matter is 1.72 x org-C% = 3.44 % Soil Organic Matter. A field of 1 hectare contains 1,000,000 dm2 x 2 dm = 2,000,000 dm3 soil in the 0-20 cm topsoil. With a bulk density of 1.4 kg/dm3 the weight of this topsoil is 2,800 ton.

The topsoil therefore contains 96.3 ton organic matter. With an estimated annual decomposing rate of 3% a total of 3 ton organic matter is lost annually.

Organic manure has a humification coefficient of 0.7 (source: Handboek voor bodem en bemesting) meaning that 70% of the organic matter in the manure will contribute to the soil organic matter. This is also named effective organic matter. On average about 100 kg per ton total weight heap manure contributes to the soil organic matter. As a result, approximately 30 ton/ha cow heap manure is required to maintain the soil organic matter. When considering dry chicken manure with rice husk (Postal) effective organic matter is estimated at 120-130 kg per ton and when using chicken manure, a total of 25 t/ha is required to maintain soil organic matter content.

3.2.2 C/N ratio

Organic materials with a C/N ratio lower than 15 will be supplying nitrogen while materials with a C/N ratio higher than 40 will immobilize nitrogen in the soil. A C/N ratio close to 24 has a low risk of crop damage since at that ratio an equilibrium is present where the decomposing process of the organic material will utilize the nitrogen from the organic material and thus not immobilize or release nitrogen. Organic material with a C/N ratio below 10 will release very fast nitrogen in the form of nitrogen. In case soil organisms are not able to convert the ammonium into nitrate the plant will take up a lot of ammonium which will cause crop damage. In the case of Pengalengan and Lembang where soil pH is low this might be possible. Sumarni et al. (2010) however, did not observe a yield reduction with chicken manure showing a C/N ratio of 6. On the contrary the treatment with chicken manure showed a higher yield than the treatment with cow manure having a C/N ratio of 13. The cow manure used in that experiment had significant lower nitrogen, phosphorus and potassium levels. Since chicken manure has a faster mineralization process the risk still is present that higher quantities of nitrogen will be lost compared to the slower mineralization of cow manure where the crop uptake can keep up with the mineralized nitrogen and thus less losses are present.

3.2.3 Contamination hazards

In terms of contamination hazards of vegetable crops with bacteria, virus or parasites, e.g., contamination with E. coli, Salmonella or Listeria, the manure used in horticulture should be decomposed very well and preferably incorporated in the soil before planting (Millner, 2009). Another risk of using organic manure is the presence of high levels of heavy metals (Naeem et al., 2020; Qian et.al., 2020). With regard to Indonesian situation, studies performed by Promono et al., (2008) and Setyawati (2015) showed heavy metals (e.g., Zn, Cu, and Pb) are present in cattle manure, but values of these heavy metals were below standard maximum values.

3.2.4 Yield effects

In Indonesia effects of manure on crop yields has been observed as well. Several experiments have shown good yields of vegetable crops with the use of 15 to 20 t/ha cow manure only (Parluhutan and Santoso, 2020; Ufairah and Sugito, 2019; Rochman, Suryanto and Sugito, 2017).

In both cauliflower and mungbean the yield was similar or slightly better with the use of cow manure only than with applying chemical NPK at similar nutrient rates (Simarmata et al., 2016; Sumarni et al., 2010) However, manure did not have an effect on soil fertility or quality in such a one-year experiment. Also, in another study in which the use of cow manure was compared with the use of chemical NPK fertilizer in mung bean, no significant differences on yield were found (Sutrisno, 2018).

In vegetable crops the use of plastic mulch is quite common nowadays in Indonesia. Main reason for using this is to suppress weed growth. Another benefit of using mulch is that it will prevent erosion and leaching of nutrients and has a positive effect on water retention. When applying organic matter in combination with mulch, the decomposing manure will also release CO_2. Since this will be trapped underneath the mulch it can only escape through the holes where the plants are. The plants can utilize the CO_2 and an increase in yield can be a result. On the other hand, when using plastic mulch ammonium concentration can increase due to higher soil temperatures generated under the mulch which can cause damage to the crop (Barker and Mills, 1980). This risk is higher with chicken manure where nitrogen content of the manure higher is than in cow manure. Especially when C/N ratio of manure is low the risk of excessive ammonium causing crop damage is high.

3.3 Views of dairy cooperatives

3.3.1 Current manure management on member dairy farms

Based on interviews with the dairy cooperatives, it was found that manure management is largely absent in the dairy farms of all 5 cooperatives. According to dairy cooperatives, most of their member dairy farmers only collect part of the faeces and discharge all the urine. The farmers wash the cows, of which the rinse water is also considered as waste. Respondents’ estimated 60 to 90% of the total production of manure on member dairy farms was discharged into the environment (Table 12).

Table 12 *Respondents' estimates of the proportion of discharged manure and current manure management practices in smallholder dairy farms in West Java Province.*

Respondent	Number of dairy farms	Estimated proportion discharged manure	Manure management
KPSBU Lembang	4,500	80%	• Applied manure to crop land or forage cultivation areas • Biodigesters • Selling manure • Compost • Small scale-piping system for solid and liquid manure • Giving manure to crop farms
KPGS Garut	1,200	90%	• Applied manure to crop land or forage cultivation areas • Biodigesters • Vermicompost (Kascing) • A few of selling manure • Giving manure to crop farms
KSU Karya Nugraha Kuningan	1,100	80%	• Applied manure to crop land or forage cultivation areas • Biodigesters • Vermicompost (Kascing) • Traditional water waste management • Locally-Pumping system for solid and liquid manure • Trials for making paper from solid manure • MoU with the Regionally-Owned Enterprises (PUD) for manure use • Giving manure to crop farms
KSU Tandang Sari Sumedang	840	70%	• Applied manure to crop land or forage cultivation areas • Biodigesters • Giving manure to crop farms
KPS Pengalengan	2,200	60%	• Applied manure to crop land or forage cultivation areas • Biodigesters • Vermicompost (Kascing) • Giving manure to crop farms

Practices of applying manure to the land (crop or forage cultivation areas), anaerobic digestion, and composting or vermicomposting ('kascing') could be found in all 5 dairy cooperatives (Table 12). The practice of selling manure was mentioned by KPSBU Lembang and KPGS Garut only, whereas giving away manure (in a small amount) to crop farms was done by all dairy cooperatives. The use of a piping system to flow manure to the crop or forage cultivation areas was found at only a small group of farms (less than 20 farms) in KPSBU Lembang and KSU Tandang Sari Sumedang.

Figure 3.2 shows respondents' views of issues associated with the lack of manure management in the region. All respondents agreed that discharging manure creates nuisance for locals, particularly when stables are close to the settlements. Dairy farmers in urban areas have limited options to implement manure management and are considered as a problem to local inhabitants. For example, in KSU Karya Nugraha Kuningan locals demonstrated against the presence or dairy farms and filed complaints to the police about large amounts of discharged manure from dairy farms. Four out of the 5 respondents indicated that discharging manure would pollute the rivers and two respondents indicated it would pollute drinking water sources. They indicated that since most dairy farms are located in the upper areas; the discharged manure flows from the high areas downwards and contaminates water sources, including rivers, downhill.

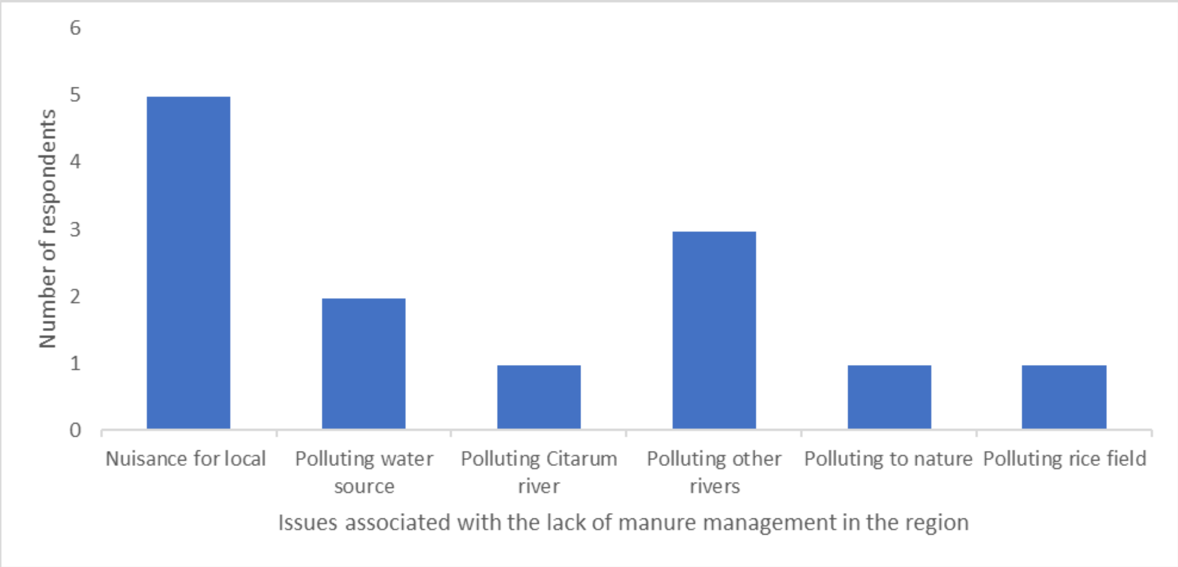

Figure 3.2 *Respondents' views of issues associated with the lack of manure management in the region.*

Pollution of the environment, the Citarum river, and rice fields were only mentioned once as issues of wrongly discharged manure. These issues are related to region-specific situations. For example, pollution to the Citarum river was only indicated by KPSBU Lembang because this is the only dairy cooperative situated in the Citatrum watershed and most of their farms are located in this watershed. In addition, environmental pollution was indicated as well since tourism is an important sector in the same region as where KPSBU Lembang operates. In KSU Karya Nugraha Kuningan pollution of rice fields was indicated because this region is one of the major rice producing centers in West Java province (BPS, 2019). The issue with the rice field is linked to irrigation water, being use for irrigating the rice field, has been contaminated with abundant nutrients from discharged manure. Paddy plants are growing due to nutrients from manure but assumed to be overfertilized, which negatively impacted the quantity of rice production (i.e., less rice produced).

As leading authorities, the dairy cooperatives have made attempts to reduce the discharge of manure. Table 13 shows the initiatives of dairy cooperatives to reduce this discharge.

Table 13 *Initiatives of dairy cooperatives to reduce discharging of manure.*

Respondent	Manure management initiatives
KPSBU Lembang	• Supporting biodigester instalment by providing loans for dairy farmers • Providing manure training for dairy cooperative • Actively involved in research, project and training related to manure management • Initiating collaboration with tea plantation
KPGS Garut	• Socialization and education for the farmers • Initiating collaboration with private sectors • Bridging loan to construct Biodigester
KSU Karya Nugraha Kuningan	• Initiating small water waste management • Initiating large biodigester instalment (zero waste concept) • Communal piping system • Working with the local enterprise to manage manure • Saung program[1)] • Subsidy for small water waste management
KSU Tandang Sari Sumedang	• Initiating collaboration with forestry • Socialization and education for the farmers
KPS Pengalengan	• Socialization and education for the farmers • Bridging loan to construct Biodigester

1) A program in which dairy farmers could request a loan to buy a roof-cover for manure storage

All dairy cooperatives indicated the biogas program as a solution to the issue of manure discharging (this seems to be a misperception of cooperatives, and further discussed in the Discussion section). The Indonesian Government supported this program via the Ministry of Energy and Mineral Resources (ESDM) and private sectors. In 2009, the biogas program was initiated, and the BIRU (Biogas Rumah; Biogas at home) was launched. Constructing a biodigester requires a high initial investment, and not all smallholder farms can pay such a vast amount. Hence, some dairy cooperatives (i.e., KPSBU Lembang, KPGS Garut, KPS Pengalengan) provided loans or bridging loans to other private sectors.

Dairy cooperatives were actively promoting and socializing the importance of performing manure management. For example, dairy cooperative KPSBU Lembang actively encouraged their dairy farmers to participate in manure management training (e.g., composting) to improve their knowledge. In addition, this cooperative also supported research related to manure management, being performed by universities and research canters.

KSU Karya Nugraha Kuningan, together with the dairy farms in Cipari village, built a piping system via which liquid and the solid manure flows to a communal wastewater The piping system was funded by the dairy cooperative (30%) and the dairy farmers (70%). The dairy cooperative initiated a collaboration with the Regionally-Owned Enterprises (PUD). This local enterprise picks up the manure and composts the manure into a product to be used by farmers (e.g., crop farms, flower farms). The dairy cooperative also initiated a *Saung program*. In this program, the dairy farmers could request a loan to buy a roof-cover (e.g., plastic). The roof-cover is to be used to prevent rain water from diluting manure. More water content in the manure means higher risks of leaching or run off and at the same time the product will be more awkward to transport due to its lower dry matter content. KSU Tandang Sari Sumedang initially collaborated with the forestry sector (Perhutani; State-own enterprise) allowing dairy farmers to apply manure on fields for forage production in the forest area. However, this activity was discontinued due to the long transport distance of the manure to the designated locations.

3.3.2 Perceived constraints to manure management

All dairy cooperatives indicated that the limited land holdings either for manure storage or manure application and the absence of a manure market was the most important constraints to manure management in West Java Province (Table 14). The land issue is associated with the fact that the dairy farms have little to no land for storage and application. The manure market issue is associated with the absence of formal agreements between dairy farms and crop farms. This leads to uncertainties in the supply chain of cattle manure to crops farms, both for the supplier (dairy farms) and buyer (crop farms). So far, agreements between crop and dairy farms are performed occasionally, meaning that the crop farms would only use manure in certain circumstances (e.g., at the beginning of the cropping season). The demand for manure is uncertain outside of this season. Also, there is much variation in the price of manure among farms (e.g., ranging from 3,500-10,000 IDR per sack with a content between 30-50 kg of fresh manure).

All dairy cooperatives indicated that issues from biogas program are related to the investment cost and maintenance process. To construct a biodigester, the farmers need to invest and most often loans are then required. Small-scale farms cannot afford to pay for the construction of a bio-digester themselves. Hence, some dairy cooperatives provide loans to their members. The private sector with Rabobank and UNEP as examples, also provides loans on a commercial base. Due to the lack of maintenance of the constructed biodigesters, some farmers complain about defect biodigesters, and some biodigesters are no longer in use, therefore. Dairy farmers admit that the utilization of bio-slurry is low due to the liquid form of bio-slurry which is difficult to transport, being another issue within the bio-digester program (this issue is further discussed in the Discussion section).

A modification of the biodigester program with a 'zero-waste concept' was done in KSU Karya Nugraha Kuningan demo farm, in order to utilize manure from the demo farm and to reduce the discharge of bio-slurry (or 'digestate'; the by-product of bio-digester production). In this pilot project an integrated bio-digester was built with a 50 m^3 capacity, where afterwards the bio-slurry is filtered in order to separate the liquid and the solid fractions. After several times of filtration, the solid part is expected to be used as organic fertilizer and the liquid part is flushed to the river.

Solutions for utilization of cattle manure explored with other parties seemed often not profitable for the dairy cooperative and dairy farmers, which was perceived as a constraint for manure management by KPGS Garut. For example, private composters are willing to buy the solid manure, but are asking the dairy cooperative to sell their product. The long distance of delivering manure (e.g. from dairy farms in Garut to the processor in Tasikmalaya is 117 km, taking up 2 - 3 hours trucking) is a main constraint, causing that manure processing is not economically feasible. Consequently, such initiatives were abolished.

In KSU Tandang Sari Sumedang, there was an initiative to use manure from individual dairy farms by a private company, but without involvement of the dairy cooperative. The dairy farmers did not meet the standard of product (e.g., solid manure was mixed with the soil), causing that the private company terminated the agreements.

Also in KSU Tandang Sari Sumedang, a collaboration program was started between the dairy cooperative and Perhutani (forestry), but this program did not work out well due to the long-distance between dairy farmers and the forestry area. Most dairy farms in Sumedang were centralized in an area far from the forestry area (60 km). The distance is associated with high cost of transporting manure. Manure needs to be transported to the forest areas, mostly located in the steep hills, and the infrastructure (i.e., road) is challenging. According to the dairy farmers, manure payments by Perhutani were insufficient to meet the cost of transportation. Therefore, this program lasted only for less than one year.

Table 14 *Constraints to manure management as perceived by dairy cooperatives.*

Respondent	Manure management constraints
KPSBU Lembang	• Land availability • Manure market • Investment and maintenance for biodigester
KPGS Garut	• Land availability • Investment and maintenance for biodigester • Unmanaged bio-slurry • Lack of profitable manure management solutions • Manure market
KSU Karya Nugraha Kuningan	• Land availability • Manure market • Investment and maintenance for biodigester • Unmanaged bio-slurry
KSU Tandang Sari Sumedang	• Land availability • Defect biodigester • Manure market • Investment for biodigester • Lacking maintenance for biodigester • Distance from barns to land • Lack of communication between dairy cooperative and third parties (potential processors and users) • Distance from dairy farms to forestry
KPS Pengalengan	• Land availability • Manure market • Investment for biodigester

3.3.3 Perceived opportunities for improvement of manure management

Dairy cooperatives were asked to indicate opportunities for utilizing dairy cattle manure on a large scale. The issue related to space for storing manure was indicated as an important constraint for manure management: two of the five dairy cooperatives perceived a communal manure storage system as a potential opportunity. The communal storage system could be constructed, for example, based on the location of farmer groups. Developing a communal manure storage could save cost for transportation of a large user for collecting manure and at the same time enhance manure collection from farms. In a similar vein, KSU Karya Nugraha Kuningan considered the communal piping system to be an effective approach and large-scale solution for reducing discharged manure. This approach is still in the piloting phase, as PUD is now initiating to collect manure from the pond of the communal piping system.

According to KPSBU Lembang and KSU Karya Nugraha it is essential to create a manure market (Table 15). They stressed research is needed to develop the manure market, and to identify market requirements (e.g., dairy farmers and crop farmers), including product quality and pricing. KPSBU Lembang indicated the tea plantation (i.e., managed by PTPN; State-own plantation enterprise) is a potential larger-user. The tea plantation area in West Java is 87,608 ha (Statistic, 2019). To initiate the program, KPSBU Lembang suggests starting a pilot project to better understand the effect of manure application on tea plantation areas. However, so far, the dairy cooperative and the tea plantation board have not reached an agreement to start a pilot.

According to KSU Tandang Sari Sumedang, the forestry area ('Perhutani'; State-own forest enterprise) is a potential larger user, despite failure of previously initiated programs. To solve the issue of the long-distance from dairy farms to the forestry area, manure should be collected first in a communal storage before being delivered to the forestry area.

According to KPS Pengalengan, the coffee plantation and horticulture sectors are potential large users. Coffee and potatoes are important commodities in Pengalengan. In addition, the dairy farmers need to be educated continuously about the importance of managing manure at their farms.

Table 15 *Potential large-scale opportunities for improving manure as perceived by dairy cooperatives.*

Respondent	Manure management opportunities	Potential large-scale user
KPSBU Lembang	• Developing manure market systems	• Horticultural sector • Tea plantation
KPGS Garut	• Picking up manure from dairy farms • Communal manure storage	• Horticultural sector
KSU Karya Nugraha Kuningan	• Replicating the communal piping systems and communal wastewater management. • Composting • Manure market	
KSU Tandang Sari Sumedang	• Pilot project for manure application in forestry land • Research on feasibility study related to manure application • Communal manure storage • Transporting (solid and liquid) manure	• Forestry sector • Tea plantation
KPS Pengalengan	• Organic fertiliser processing located in Pengalengan • Socialization and education for dairy farmers related to manure quality • Temporary communal manure storage • Horticulture (potato) and plantation (coffee)	• Coffee plantation sector • Horticultural sector

3.4 Views of potential large-scale users

Opportunities of utilizing cattle manure in agriculture in West Java were further explored in interviews with respondents from three potential large-scale users indicated by dairy cooperatives: coffee plantation, forestry, and horticulture sectors. A respondent from tea plantations could not be reached.

3.4.1 Coffee

Opportunities of applying cattle manure on coffee plantation areas in West Java Province were discussed with a coffee farmers' group leader (i.e., Kelompok Tani Rahayu). The farmer group is located in Pengalengan sub-district, Bandung Regency, West Java Province. The farmer group was established in 1999 and has currently 211 members, selling raw coffee beans and processed coffee (dried beans). Each group member manages approximately 1-2 ha of coffee plantation with a total of 350 ha for the whole group.

With regards to fertilizer use, most of the member farmers use NPK as inorganic fertilizer and chicken manure as organic fertilizer. The rate of NPK Phonska for the immature plant is 100 g/plant/year (0.25 t/ha/year; 2,500 plants/ha) and organic fertilizer 4 kg /plant/year (10 t/ha/year). The rate of NPK Phonska for the mature plant is 750 g/plant/year (1.9 t/ha/year) and organic fertilizer 7 kg /plant/year (17.5 t/ha/year). Chicken manure was considered the most suitable organic fertilizer for coffee plantations because of the high content of N and P required for the coffee plant's productivity. Although chicken manure is essential, the farmer group leader believes in the importance of cattle manure for soil productivity due to the organic matter content. Hence, on his own land, different types of organic fertilizer are applied as a mix (i.e., chicken manure (40%), goat manure (30%), cattle manure (20%), and additives (10%)). In his experience, mixing these three types of organic fertilizer increased coffee productivity and improved soil quality. In case all members would use dairy cattle manure, the farmer group leader estimated about 1,225 t/year of dairy cattle manure would be required for the farmer group.

Farmer group leader

"I do see the importance of cattle manure for the soil. I also see why most coffee farmers use chicken manure, it is all about the cost and practical aspects"

3.4.1.1 Perceived constraints to using cattle manure

According to the farmer group leader, the coffee farmers perceive chicken manure as the most suitable organic fertilizer due to the price and practical aspects (e.g., easy to transport and to apply on the field). Chicken manure could be found easily, and the supplier delivers chicken manure to the field. The cost for chicken manure is also affordable (300 IDR/kg including transport and handling). Chicken manure is therefore a serious competitor with cattle manure.

According to the farmer group leader, when various types of manures are used another constraint is the need for a storage place and mixer for mixing the manures. For these famers need to invest for which they most often lack capital. Even when the dairy farmers provide the manure for free, the cost of collecting manure is high (i.e., for transportation and labour). In addition, the available dairy cattle manure is most often only the solid part (dung), rich in P but with a relative low N content, while the liquid part (urine) rich in N is also required to meet the crop nitrogen requirement.
He also indicated that continued supply of dairy cattle manure is an issue. According to his experience, dairy farmers have less commitment to collect and store manure in a proper way. Hence, the supply of dairy cattle manure is inconsistent and could affect the coffee production.

3.4.1.2 Perceived opportunities for using cattle manure

According to the farmer group leader, to switch from chicken manure to dairy cattle manure, research on applying dairy cattle manure to coffee plantations is required. The pilot research should be directed to analyse the effects of dairy cattle manure on coffee production. The output of this research is important in order to ensure other coffee farmers about the benefits of dairy cattle manure for coffee production. He suggests the research could be done on mature plants with different rates of fertilizers. For the mature plants, the effects of fertilizer could be seen after four to six months. If there is research on fertilizer application, he is willing to cooperate and provide land for the pilot program.
The next important step is to educate the coffee farmers to adopt dairy cattle manure, which is vital to create awareness of coffee farmers to use dairy cattle manure.

3.4.2 Potato and cabbage

Potato and cabbage are important commodities in Indonesian horticultural production (Natawidjaja et al., 2007). To understand constraints and opportunities for manure application in potato and cabbage, we interviewed a large crop farmer, owning 50 ha of crop land in Pengalengan, Bandung Regency, West Java. His farm was established in 1990, and currently, there are 100 workers. He cultivates potatoes, cabbages, and carrots in a rotation sequence. Part of the products is exported (e.g., Thailand) and part is sold locally.

Regarding fertilizer use, he uses NPK Phonska as inorganic fertilizer and chicken manure as organic fertilizer. The rate for fertilizer differs for each vegetable. He applied 1.5 ton NPK/ha and about 30 ton/ha of chicken manure in the case of potatoes (one cycle is 4 months). The cost for chicken manure was about 200-300 IDR/kg. When he established his farm, he applied cattle manure on his field. At that time, he mixed cattle manure (60%) and chicken manure (40%). He estimated 2,700 tons of fresh dairy cattle manure per year was used on his farm.

According to his experience, cattle manure could improve soil productivity, but this process takes time. The farms are growing, and the demand for his products increase. Hence, he needs a shortcut to increase the production, and this was done by replacing the cattle manure with the chicken manure. According to Mr. Harry, replacing cattle manure with chicken manure significantly increased productivity and reduced the farm’s cost. In his opinion, crop farms are willing to use cattle manure if the cattle manure cost is affordable and practical.

3.4.2.1 Perceived constraints to using cattle manure

The constraints for cattle manure are associated with the cost and practical aspects. The cost of using dairy cattle manure is mostly for labour and transportation. The dairy farmers often give the manure for free, but the labour and transport cost is for the crop farmers. He estimated the cost for fresh cattle faeces is about 500 IDR/kg (including handling and transport).

Additionally, the crop farms cannot use the fresh cattle faeces immediately. It must be stored for at least four months before being used. This storing system requires space, and additional investment is required to construct the storage.

3.4.2.2 Perceived opportunities for using cattle manure

To increase the use of manure at the crop farms, he suggests the dairy farms do the drying of the manure, to reduce water content. The dried manure is composted, light and ready to be used for crop farms. If possible, the dairy farmers could even grind it, for the final product to have a “similar texture as the soil”. The crop farmers need to be educated to switch from chicken manure to cattle manure.

> a large crop farm
>
> *“My grandfather taught me the importance of cattle manure for the soil, but I need fast results. The response of chicken manure is quick, and I can see the immediately the results”*

3.4.3 Forestry

To further explore the opportunities of manure application on the forest areas, we interviewed the assistant of the KPH North Bandung. In this area two types of applications are present, one to the trees and the other one to forage crops that are grown in the forest area.

The KPH North Bandung has a formal agreement with the dairy cooperative (KPSBU) for manure application in the forest areas. Parties in the agreement are the KPH North Bandung, the local community which actively involved in nature protection (LMDH) and the members include the dairy farmers of KPSBU located nearby the forest areas, and KPSBU. The agreement aims to optimize the function of the forest area and to provide land for forage cultivation. The agreement initially started in

2010 and renewed every three years (i.e., the current agreement from 2019-2021). In this agreement, the dairy farmers can use 165 ha of the forest protection areas for cultivating forage.

The KPH North Bandung is responsible for providing land, ensuring the security of planted forage, and, together with KPSBU, to perform monitoring and evaluation. The dairy farmers are responsible for preparing the land, planting, and maintenance, including mandatory application of fertilizer (i.e., urea and organic fertilizer) and harvesting. KPSBU is responsible for paying costs of forage cultivation and performs monitoring and evaluation. The principle of the agreement is profit sharing. The harvested forage can either be sold to other dairy farmers or, against a fee, can be used by the dairy farmers who are involved in this agreement. The selling price of this produced forage is IDR 250 per kg. The profit of selling forage is shared between the dairy farmers (70%) and the forest management (25%). The remaining 5% is for village benefits in the forest area.

The potential manure application in the forest area was estimated according to assistant of the KPH North Bandung. Assuming the tree spacing is 1x1 m, and manure application (in the form of compost) is 2 kg per month per tree. With a total area of 165 ha, he estimated the required compost is 330 t/month or 4,000 t/year.

According to KPH North Bandung a major constraint of this collaboration is the location of the planted forage. The KPH North Bandung has designated areas for forage plantation to be grown by dairy farmers, but the farmers often plant at other locations, in which case nutrients from applied fertilizer could potentially affect water reservoirs. In the catchment areas of water reservoirs, it is prohibited to cultivate forage because of its ecological functions and to avoid the invasive weeds in this area, but the dairy farmers nearby this area cultivate their forage still there. To solve this issue, the KPH North Bandung educates and warns the dairy farmers of the importance not to plant forage at those places.

In addition, for dairy farmers located near the forest area the distance itself is not an issue. However, the poor infrastructure (i.e., road) is a constraint for those farmers still, making it difficult to transport manure into the forest area.

According to KPH North Bandung, the agreement between dairy farmers and the forestry sector has benefits to all parties. Therefore, KPH expects such collaboration will be continued and improved. For instance, KPH indicated the land size for forage area needs to be increased, so more land can be fertilized with dairy cattle manure.

3.5 Views of Provincial Government

The issue of manure discharging from dairy farms, and related regulations and programs were discussed with the head of department of the Food Security and Livestock Services of West Java Province, and the head of department of Water and Air pollution of the Environmental Services of West Java province.

Food security and Livestock Services of West Java Province
The Food Security and Livestock Services of West Java Province is the member of group work *(Pokja)* for Citarum Harum program (Chandra et al., 2018). The Pokja was established in 2018 with the aim to handle waste from industrial and livestock that are potentially polluting the Citarum river. According to Food Security and Livestock Services, the discharged manure from dairy farms is polluting the environment, especially for the Citarum River. Since the Citarum program has been launched, environmental pollution by dairy farms gets more attention from the local government, and discussions with the dairy cooperative (KPSBU) took place to find potential solutions.

Based on the discussion with KPSBU, the Food Security and Livestock Services are aware that the land availability and the absence of a manure market are major constraints for the dairy farmers in the Lembang region (see section 3.2). To deal with this issue, at the end of 2020, the local government initiated a collaboration with potential manure processors Pupuk Kujang (Indonesian fertilizer company) and Gerakan Nasional Hijau (NGO). The collaboration included the instalment of fertilizer processing equipment for small scale and buying the compost and faeces from dairy farms. Moreover, Pupuk Kujang will process dairy cattle manure into organic granular fertilizer. Since this initiative just started, some technical issues are still under discussion (e.g., the location of fertilizer processing, manure selling mechanism, etc.).

Environmental services, West Java province
With regards to the pollution from manure of dairy farms, the Provincial Environmental Services initiated the pilot project of biogas program in 2010 and received positive reactions from the dairy farmers. The biogas program was then set as a national program and was taken over in 2011 by the Indonesian ministry of Energy and Mineral Resources (ESDM) and massive biogas plants were constructed.

With regards to the pollution from dairy farms to Citarum river, Environmental Services coordinates the Pokja for Citarum Harum program. The Pokja handles not only waste from livestock but also industrial waste. Whereas industries are monitored and enforced to meet waste management regulations (fined or temporary closed), waste management cannot be enforced to the livestock sectors, since currently it is not mandatory for small farms to report on environmental performance of their farm regularly.

To tackle the pollution issue from smallholder dairy farmers, the Pokja, together with The Food Security and Livestock Services West Java Province, initiated some programs, such as educating the dairy farmers living nearby the Citarum river. The education aims to raise the awareness of the dairy farmers for not discharging manure into the river. In addition, the Pokja also supports the Corporate Social Responsibility (CSR) program of the water processing private company (Perusahaan Jasa Tirta Air; PJTA) for wastewater management. Together with the Ministry of the Environment, the Pokja constructed wastewater management systems near dairy stables that are close to the upstream part of the Citarum river. There are some challenges for this initiative, such as dairy farms being scattered making it difficult for collective wastewater management systems to be effective, low awareness for managing manure from the dairy farms, and land issue.

The head department for water and air pollution indicated that the most effective way to reduce pollution from the manure of dairy farm is by educating farmers continuously about the importance of manure management, and the initiatives being proposed should bring economic benefits for the dairy farmers.

> The head of the Department for Water and Air pollution, Environmental Services, West Java province
>
> *"We can introduce the technologies but if the awareness is absent, the efforts would be pointless"*

4 Discussion

This study explores opportunities for utilization of dairy cattle manure in agricultural sectors in West Java Province in Indonesia. Interviews were conducted with various important stakeholders, including 5 dairy cooperatives covering a large part of the dairy sector in West Java, representatives of various agricultural sectors (coffee, horticulture, and forestry), and provincial governments. As only one respondent per agricultural sector was interviewed (i.e. a group leader of coffee farmers; a large horticultural farmer growing potatoes, cabbage and carrots; and a representative of a large forest area), it should be noted their personal views are not necessarily representative of the total sector and, hence, these results should be interpreted with care. A respondent of a tea plantation could not be found, of whom views are thus lacking.

Impacts of poor manure management

Representatives of dairy cooperatives estimated the proportion of discharged manure was between 60 and 90%, which is in line with previous findings in this region (e.g. De Vries and Wouters, 2017). As nutrients in manure are also lost from fertilized fields (nutrient leaching and run-off), the total share of nutrients ending up in ground and surface waters will be even higher. The excess of nutrients in ground and surface waters is known to cause eutrophication, and can also lead to contamination of drinking water sources (Biagini & Lazzaroni, 2018; WHO, 2016). Dairy cooperatives, however, unanimously responded local nuisance was a main issue, whereas pollution of surface waters, nature and rice fields were mentioned by fewer cooperatives. In addition, the latter issues were region-specific, depending on the geographical location and local economic activities (proximity to rivers and tourism in Lembang, paddy production in Kuningan). This means it is important to customize solutions to region-specific issues. For instance, paying more attention to manure management on dairy farms close to rivers, rice fields or urban settlements; or, when nuisance is found to be the main issue, prioritizing solutions for solid manure over liquid manure.

Potential large-scale users in agriculture

Dairy cooperatives identified the following agricultural sectors as potential large-scale users of cattle manure: horticulture (mentioned by 3 cooperatives), tea (2), coffee (1), and forestry (1). One dairy cooperative did not indicate any large-scale user, but only techniques to process manure, without specifying a concrete end-user. Differences between cooperatives indicate that the type of large-scale user is area-specific, due to differences in agricultural commodities grown in those areas. Jointly the four agricultural sectors identified by dairy cooperatives occupy 904 thousand ha in West Java: 602,532 ha forestry, 164,338 ha vegetables and herbs; area of fruit unknown, 90,499 ha tea, 47,082 ha coffee. Assuming an application rate of organic fertilizer of 17.5 tons/ha/y in coffee (rate based this report) and tea, and 15 tons/ha/y in vegetables and herbs (Pronk et al., 2020), theoretically about 5 Mtons of organic fertilizer could be applied on coffee, tea, vegetables and herbs (ignoring forestry because of uncertainty in potential area that could be used for manure application). Currently mostly chicken manure is used as organic fertilizer for these commodities.

Identified potential users by dairy cooperatives were likely more related to the size of land area owned by these parties, rather than the relevance of cattle manure as organic fertilizer for these sectors. It is important to further investigate the agronomic benefits of cattle manure as a fertilizer for these commodities, as well as for other agricultural sectors that could pay for high-quality manures or composts, e.g., the nursery crop sector, orchard mulching, media for hydroponics e.g., strawberry production and organic farming. Good results have been shown with organic manures, after proper composting, as alternative for peat as growing media in the nursery crop sector (Moral et al., 2009).

Theoretical benefits and disadvantages of using cattle manure in horticulture

As described in this report, applying organic manures adds macro-nutrients (N,P,K) and micro-nutrients required for plant growth, and can have benefits for soil chemical and physical properties and soil biology. While macro-nutrients can be added by chemical fertilizer and by chicken manure, which is relatively rich in N and P, stakeholders interviewed in this study emphasized the value of cattle manure for soil quality, particularly due to the organic matter contents. The same was found in the study of Pronk et al. (2020): according to horticultural farmers in Lembang, important drivers for using cattle manure are improved soil fertility, easier soil cultivation and increased crop yields. In the presented study it was calculated that for the situation in Pengalengan and Lembang an annual application of 30 t/ha cow manure or 25 t/ha chicken manure would be required to maintain the organic matter level of soils. This is in line with other recommendation rates for organic fertilizer for vegetable crops (20-30 tons per ha, e.g., Moekasan et al., 2015; Setiawati et al., 2007) and higher than average amounts applied in practice (13-17 t/ha, Pronk et al., 2020; although chicken manure is applied in higher amounts: 21-28 t/ha). If farmers would increase application rate to 25-30 t/ha, this would increase the estimate of the total amount of organic fertilizer that can be applied on land of large-scale users (see previous paragraph). Organic matter maintenance, however, is likely not a priority for farmers, as no immediate effect in crop yield is visible and organic matter in andosols is relatively high. This was confirmed by the horticultural farmer interviewed in the present study, who indicated improvement of soil productivity by cattle manure takes too much time, whereas fast results are needed to meet the growing demand.

Based on the recommended fertilizer rates by Setiawati et al., (2007); incl. organic fertilizer, total nutrient inputs were found to be much higher than calculated crop requirements based on the nutrient removal with harvested products in this study. This suggests that these recommended fertilizer rates are too high with regard to supply of (macro) nutrients, whereas recommended fertilization rates for organic manure are in line with our calculations for organic matter maintenance. If 25-30 tons of organic manure is applied for maintaining organic matter in soils, fertilizer application rates for chemical fertilizer could be reduced.

A main disadvantage of organic manure, however, is that the nutrient content shows large variation and is often unknown. Insight in nutrient contents of organic manures is important, therefore, for the farmer to decide how much is needed and how much chemical fertilizer should be added to complement for each nutrient. The same holds for the uncertainty around the timing of release of nutrients from the organic matter. More insight of farmers in nutrient composition of manures and soils in relation to plant nutrient requirements could be enhanced by more regular manure and soil testing. The local government could play a role in facilitating this. Manure can also pose risks of contamination of food or feed crops with unwanted biota, such as parasites and pathogens. Fresh, wet manure can damage horticultural crops when applied as mulch, but not when the manure is broadcasted and well incorporated in the soil before planting.

Cattle manure vs. chicken manure

Chicken manure is more appreciated by horticultural farmers than cattle manure (Pronk et al., 2020). Most horticultural farmers apply chicken manure products (70% of farmers in Lembang), while fewer farmers use some form of cattle manure (12%), or combinations of various types of organic fertilizers. According to a stakeholder interviewed in the present study, the presence of chicken manure is a constraint in using cattle manure, because of perceived higher nutrients in chicken manure, and because of the various practical advantages of chicken manure. Farmers' perceptions on the high nutrient contents of chicken are substantiated in literature, which shows that, compared to cattle manure chicken manure generally contains higher concentrations of N and P, and unlike cattle, poultry excrete a mixture of organic N and uric acid N (relatively quickly mineralized and available to plants). Furthermore, the practical advantages of chicken manure were also indicated by farmers in the study by Pronk et al. (2020), including: ease of obtaining, low transportation costs, and availability at all times. In the study by Pronk it was also indicated by farmers that a perceived advantage of cattle manure over chicken manure was that "cold (fermented) cattle manure does not burn crops". This was not indicated by stakeholders in the present study, but was the most important driver for using cattle manure for horticultural farmers in the study by Pronk et al. (2020). As explained in the present report, this risk of crop damage is known to be higher with chicken manure as the nitrogen content of this manure is higher (ammonium toxicity, C/N ratio below 10) than in cow manure. Knowing which crops are more sensitive to ammonium toxicity, therefore, might help to identify specific suitable crops for cattle manure.

Combining cattle manure with other organic fertilizers is common practice. For example, in Lembang the combination of cattle manure and 'postal' (chicken manure with rice husks) was the most important organic fertilizer for broccoli, which is one of the four most important crops in Lembang in terms of land use (Pronk et al., 2020). Cattle manure was also applied in the other most important crops: cayenne pepper, lettuce and tomato.

Stakeholder views of constraints to using cattle manure

According to most dairy cooperatives a general constraint to improved manure management is the lack of land available for manure application. The scarcity of land and the competition for space among sectors on Java is expected to further increase in the future (Verhaeghe and Zondag, 2009). According to one cooperative (KSU Tandang Sari Sumedang), also the distance from stables to land is a main issue. This is confirmed by previous research which showed that proximity to land plays an important role in manure application by dairy farmers: nearly all dairy farmers in Lembang owning land close to the cow stable applied cattle manure on this land, whereas very few farmers applied cattle manure to land far from the stable (De Vries and Wouters, 2017). The disconnection of land and milk production leads to high transport and labour costs of manure and feed and makes recycling of manure as a fertilizer extremely difficult (del Corral et al., 2011). In order to tackle these problems, a spatial development strategy is needed for the dairy sector in West Java, with land-based dairy farming being key to sustainable development. A land consolidation policy (i.e., readjustment of land parcels) is required to reduce the high degree of land fragmentation in dairy farming. Interviewed policy makers recognized the issue of land availability, but spatial development was not mentioned as a solution to the animal waste problem.

A second main constraint indicated by most dairy cooperatives was the absence of a manure market and the lack of economic profitability of manure sales. The present report is a first step towards the identification of these 'manure markets and their requirements. According to the dairy cooperatives, the absence of a manure market is associated with the lack of formal agreements between dairy farms and crop farms, leading to uncertainties in the supply for the supplier and buyer. This was confirmed by the horticultural large-scale farmer, who indicated that a continuous supply of cattle manure is an issue at the supply side. This suggests development of a stable and reliable manure supply chain needs to be arranged through formal agreements.

Constraints to using cattle manure indicated by large-scale users differed from those indicated by dairy cooperatives (Table 16), including price (due to costs of transport and labour); required user investments for mixing/grinding, storage (space), and labour; practical aspects (incl. ease of handling, transport and application); continuous availability of manure; and manure quality (low N content of solid cattle manure). In a recent survey among 300 horticultural farmers in Lembang, the easy and affordable delivery system was a dominant driver for using chicken manure, which could also be the case for cattle manure when this system is developed. However, the 'availability' of cow manure was not perceived as the most important barrier for using cattle manure (Pronk et al., 2020). According to these farmers, main issues are the difficulty to transport dairy cattle manure, manure being often too wet and too costly to transport, manure being often not properly packed, and the difficulty of handling and applying cattle manure. This suggests the dairy sector needs to implement improved manure processing methods that enable easier handling, transport and application, and that ensure a continuous supply. The horticultural large-scale farmer in the present study also emphasized that drying and proper processing (fermenting) of manure should be done by the dairy sector, as horticultural farmers do not want to make investments for drying, grinding or storing manure.
From a policy perspective, although national regulations on waste management do exist, waste management cannot be enforced to small-scale farmers. Government respondents emphasized the lack of awareness from dairy farmers as a constraint, and that continuous education is required to overcome this issue.

Table 16 *Constraints and opportunities for using cattle manure indicated by stakeholders.*

	Constraints	Opportunities
Dairy cooperatives	Land availability	Developing manure market
	Manure market	Technical solutions:
	Lack of economic profitability, costs of transportation Transport distance Investment and maintenance (defect) biodigesters Unmanaged bio-slurry	- communal storage - composting - communal piping system - manure separation - transport/manure pick up from dairy farms - processing into pelletized fertilizer Socialization and education
Large-scale users	Price Practical aspects Quality (low N content)	Field research on benefits of cattle manure Education of farmers (users) Increase forestry area for forage production
	Advantages of chicken manure	Technical solutions:
		- dry and grind manure on dairy farm
		- use urine (higher in N), organic matter (OM) contents of faeces
Provincial government	Waste management cannot be enforced to small-scale farms	Pelletized organic fertilizer production Education of farmers (Pokja program, Citarum)

Stakeholder views on the opportunities of using cattle manure

Large-scale users generally had a positive attitude towards using cattle manure. The positive intention towards using cattle manure was also found in the study by Pronk et al. (2020), which showed that 75% of the horticultural farmers would like to use cattle manure when barriers are overcome. The respondent of the forestry area indicated a larger forestry area could be used for cattle manure application, and the large coffee producer was open to field research to pilot effects of cattle manure on coffee.

As opportunities for using cattle manure, stakeholders mentioned socialization and education of farmers (both dairy farmers and potential end-users), and technical solutions for storing, processing, and transporting of manure. The importance of education of farmers was emphasized by all 3 groups of stakeholders - dairy cooperatives, potential large-scale users, and policy makers. In addition, between dairy cooperatives and the forestry sector the importance of using formal agreements for continuous supply and availability and ensuring economic benefits for all involved parties was emphasized. In contrast, in KSU Tandang Sari Sumedang such a formal agreement was not profitable for dairy farmers due to high transport costs, and was terminated.

Technical solutions proposed by dairy cooperatives were mainly focused on the collection (communal piping system, picking up manure from farms), storage (three dairy cooperatives proposed a 'communal storage'), and treatment (composting, manure separation, processing into pelletized fertilizer). These initiatives could contribute to solving main constraints identified by potential users: ease of handling and transporting manure (storage and treatments leading to reduction in mass and moisture of manure), required investments, storage space, and labour (to be arranged by dairy sector); and continuous availability of manure. Drying of wet cattle faeces plays a central role in these solutions in order to facilitate easier handling and transport of manure. Stakeholders indicated transport costs were a main reason why past initiatives for improved utilization of cattle manure were abolished. Technical solutions for drying manure can be costly, however, for instance due to input or investment costs, labour (composting), or energy requirements (pelletized fertilizer). Most small-scale farmers have limited access to capital (although credit funds do exist), and often lack storage space in the barn to store manure. Communal activities could help to solve such issues, and – due to its larger scale - can contribute to ensuring a continuous supply of manure. Already private entrepreneurs in West Java are successfully composting cattle manure at large-scale (selling to e.g., gardening stores in Jakarta). Costs of technical solutions will have to be balanced against a foreseen reduction in other (e.g., transport) costs or increased revenues, and the end-user should be involved to know requirements on the quality and price of the end product.

Whereas solutions proposed by dairy cooperatives mostly focused on faeces or solid fraction (possibly because of its visible nuisance), urine has an important contribution to environmental pollution, but also contains valuable nutrients for plant growth (mineral N and K). As indicated by the horticultural farmer, possibilities and perspectives to utilize urine from dairy farms should be explored, including methods for collection and upgrading.

One solution for drying manure already studied in West Java is composting. Research showed that composting can reduce weight of manures substantially, by about 70%, and increase dry matter content up to about 70% DM (Sefeedpari et al., 2020). Besides mass and moisture reduction, composting is considered as a promising solution because of its value for enhancing soil fertility, increasing crop yields, and reducing diseases (Dick and McCoy, 1992; Changa et al., 2003). Profitability of composting, however, varies among farms, whereas vermicomposting is economically profitable due to the worm sales (De Vries et al., 2019). Main costs of composting concerns input materials required for composting (e.g., postal) and labour for collection, mixing and turning, and packing. Depending on the amount of input material and labour, costs of small-scale composting on dairy farms was shown to vary between about 250 and 700 IDR/kg (Sefeedpari et al., 2020). In some cases, a high quality of compost (e.g., a fully ripened, 'cold' compost) might not be needed by end-users, in which case the cost price of composting can be lower. Requirements in quality and related cost price should therefore be discussed between supplier and user. A disadvantage of composting is the high N loss (about 40-60%) to the environment. Due to moisture loss, however, concentrations of N and P are usually higher in the final compost.

All dairy cooperatives indicated the biogas program as a solution to the issue of manure discharging. In itself bio-digestion is not a solution to the manure issue. However, as bio-slurry (digestate) is particularly difficult and costly to transport because of its voluminous and diluted properties (DM 3%, Table 3), dairy cooperatives indicated that most of the digestate is discharged, leading to loss of nutrients into the environment (Zahra W.A., et al. 2021). The issue of discharged bio-slurry was also indicated by Bonten et al. (2014). This is why KSU Karya Nugraha Kuningan initiated a pilot project to reduce the discharging by filtering bio-slurry in order to separate liquid and solid fractions. Separation of manure can yield a drier, light-weight solid fraction, which is more suitable for transport, while the liquid effluent can be used locally (or pumped elsewhere) as fertilizer (e.g., Flotats et al., 2011). KSU, however, indicated to flush the liquid fraction into the river after filtration. This should be discouraged because the liquid fraction likely still contains nutrients contributing to pollution of surface waters. Depending on the method, separation may also partition into an organic N- and P-rich solid fraction and a liquid fraction with relatively high mineral and K contents, which may be advantageous because of enabling balanced fertilization in accordance with the needs of crops. In the Indonesian situation separation can be particularly useful for bio-slurry, to avoid discharging of the wet product. The additive materials to optimize separation process (e.g., polymers and Al), however, could pose other environmental issues (Hjorth et al., 2010; Nahm et al., 2005).

When manure is not used as bio-slurry, separation of faeces and urine can also be done manually in the stable (collecting the faeces by shovel, urine at the end of the gutter), which is a low-cost separation method and relatively easy due to the fact that most Indonesian dairy farms are tie-stalls. Still farmers should be instructed to collect and store the liquid fraction as well rather than let it flow into the river. After collection faeces can be heaped or composted with a similar or higher increase in DM content than mechanical separation, and urine can be used for local application.

5 Conclusion

This study explored opportunities for utilization of dairy cattle manure in agricultural sectors in West Java Province in Indonesia. Dairy cooperatives in West Java identified four agricultural sectors as potential large-scale users of cattle manure: horticulture, tea, coffee, and forestry.

Constraints to utilization of manure indicated by dairy cooperatives were mainly the scarcity of land, lack of a manure market, and lack of economic profitability of solutions. According to potential large-scale users main constraints to utilization of manure were the related to (cost) price, manure quality, and practical aspects, including the continuous availability of manure and ease of handling, transport and application.

Large-scale users had a positive attitude towards using cattle manure. As opportunities for using cattle manure stakeholders mentioned (i) socialization and education of dairy farmers and potential end-users, (ii) various technical solutions for collection, storage, treatment (drying), and transport of manure, and (iii) formal agreements between dairy farms and end-users.

We concluded that there are opportunities for utilization of dairy cattle manure in agricultural sectors, but this requires an easy, reliable, and affordable delivery system by the dairy sector. Due to costs of solutions, the end-user should be closely involved in the development of solutions to specify requirements on the quality and cost price of the end product. Future activities should focus on development of affordable manure collection, storage, and treatment methods in dairy cooperatives, as well as education of dairy farmers and potential end-users. Furthermore, possibilities to utilize urine from dairy farms, separation techniques for bio-slurry, expanding cattle manure application in the forestry area, and field research on manure application in coffee should be explored. Parallel to technical solutions to solve the issue of manure discharging, as the increasing disconnection of land and milk production makes recycling of manure as a fertilizer extremely difficult, a spatial development strategy is needed for the dairy sector in West Java, with land-based dairy farming being key to sustainable development.

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To explore the potential of nature to improve the quality of life

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