UPPSALA UNIVERSITET

UPTEC W 23004

Examensarbete 30 hp

April 2023

Nutrient flow on agroforestry farms in the province of Son La in northwest Vietnam

Tula Strotz

UPPSALA UNIVERSITET

Nutrient flow on agroforestry farms in the province of Son La in northwest Vietnam

Tula Strotz

Abstract

The population in the high mountains of the northwest provinces of Vietnam belongs to the poorest population in the country. Among the reasons behind this are the high frequency of minority groups in the region and the infertile soils of the steep slopes. As a result of the diversified elevation in northwest Vietnam, farmers are forced to cultivate fields with a gradient of more than 25 %. Additionally, the heavy rainfall events in the region increase the runoff, which is the main mechanism of erosion. Erosion leads to loss of bulk soil, and large losses of plant nutrients. In addition to erosion, nutrient leakage also occurs especially where a surplus of nutrients is applied. This is often the case when fertilizers are not applied with care. Nutrients are a limiting factor within agriculture, and with better nutrient management, the yield, and thus the farmers’ economy, increases.

This study aimed to locate and quantify sources and sinks of nutrients within the ten chosen farms. To achieve this aim, two specific objectives were researched. The first objective was to quantify the farm gate balance to get an overall idea of nutrient surplus, deficit, and environmental risks. The second objective was to quantify and map out the internal flows i.e the field balances and the nutrients lost during manure storage. This helps locate sources and sinks of nutrients within each farm. Additionally, it will show if the grass strips help absorb nutrients lost through erosion.

The study was carried out in Mai Son District in Son La Province in northwest Vietnam. The data was mainly collected through interviews with farmers on ten farms in the study area, as well as observations made during the field visit. Five farms with cows were chosen, while five farms had no cows. The farms mainly grew maize, longan, mango, and forage grass. Additionally, analyses were made on the nitrogen, phosphorous, and potassium concentration in the compost, and the nitrogen concentration of the Guinea grass (*Panicum maximum Jacq*) which made up the grass strips in the sloping land. The Guinea leaves were analyzed to calibrate the SPAD meter used in the field to gather nitrogen values of the grass strips.

The calculated balances indicated that the elements N, P and K on each farm varied between 32 to 580 kg/ha/year for N, -680 (16) to 53 kg/ha/year for P and -130 to 220 kg/ha/year for K. It also showed that Guinea grass, when grown along the contour lines, did as anticipated; absorb excess nutrients from the soil. However, the result shows that the forage grass mines the soil from potassium. Finally, the result showed that the farmers seem to over-fertilize the plants. When estimating the nutrient lost from manure storage, the calculation showed significant losses of nitrogen, phosphorus, and potassium during storage.

The result of the study shows that the handling of manure, choice of compost or mineral fertilizer and fodder, and use of grass strips on the farms affects the nutrient loss within the farm. It also shows that a system with forage grass on the contour is, above all, effective when used on farms with grass-eating animals as the farmers otherwise don’t harvest the grass.

Keywords**:** Agroforestry, contouring grass rows, Guinea grass, nutrient losses, Vietnam

Teknisk-naturvetenskapliga fakulteten Uppsala universitet,

Utgivningsort Uppsala/Visby

Handledare: Sigrun Dahlin Ämnesgranskare: Ingrid Öborn Examinator: Johan Arnqvist

I REFERAT

Son La provinsen i nordvästra Vietnam är hem till en av de fattigaste befolkningarna i landet. Två av de bakomliggande anledningarna till fattigdomen är dels den höga frekvensen minoritetsgrupper i området, och dels att odlingsområdet är karaktäriserat med branta fält och infertila jordar. Många av jordbrukarna i området tvingas odla på sluttningar med lutningar som överstiger 25 %. På grund av Vietnams geografiska placering utsätts marken under regnperioden av många häftiga skyfall, vilket leder till kraftig erosion. Erosionen gör att större mängder jordpartiklar, men även näring, forslas bort från jorden. Den förlorade näringen kan i sin tur bidra till sämre skördar. Utöver erosionen sker även större näringsförluster till följd av ineffektiva gödslingsmetoder, där mer näring tillförs än vad växten vid tillfället kan absorbera.

Studien utfördes i Mai Son- distriktet i Son La -provinsen i nordvästra Vietnam. Information om gårdarna och fälten samlades in genom att intervjua jordbrukare på tio gårdar. Fem av gårdarna hade kor, medan fem gårdar saknade kor. På gårdarna odlades i huvudsak majs, longan, mango och fodergräs. Analyser gjordes för att bestämma mängden fosfor, kväve och kalium i stallgödslet, samt kvävevärdet i det gräs *(Panicum maximum Jacq.)*, här kallat guineagräs, som använts i gräsremsorna. Kvävevärdet i gräsremsorna i respektive fält bestämdes genom att mäta med en SPAD-meter i fälten.

Det övergripande syftet med studien var att lokalisera och kvantifiera källor och sänkor för näring på de tio utvalda gårdarna. För att nå syftet undersöktes två specifika mål. Det första målet var att göra en gårdsgrinds-balans. Anledningen var att skapa en övergripande uppfattning av gårdens näringsackumulering eller näringsbrist. Det andra målet var att skapa interna balanser för fälten samt att titta på hur stora näringsförlusterna under gödslingshanteringen var. Syftet med detta var att lokalisera vart inom gårdarna näringen främst ackumuleras eller förloras. Detta mål användes även för att ta reda på om gräsremsorna kunde användas som medel för att ta upp den näring som går förlorad vid ytavrinningen.

De beräknade balanserna indikerar att näringsbalansen på gårdarna varierade mellan 32 kg/ha/år och 580 kg/ha/år för N, -680 (16) kg/ha/år och 53 kg/ha/år för P samt -130 kg/ha/år och 220 kg/ha/år för K. Det visade även att guineagräs som odlats tillsammans med fruktträd, samt med eller utan majs, bidrog till att ta upp den kväve som annars kunde förlorats genom erosion, läckage eller ytavrinning. Gräsremsornas höga upptag av näringen verkar dock orsaka kaliumbrist i jordarna. Från analysen av näringsförluster från gödselhanteringen visade resultatet en signifikant näringsförlust för både kväve, fosfor och kalium. Näringsläckaget på gårdarna påverkas av hanteringen och val av stall- eller mineralgödsel, foder samt huruvida gräsremsorna skördas eller inte. Gräsremsor är framför allt en effektiv metod för att minska näringsläckaget i de fall de skördas. Med andra ord på gårdar som har betande djur. Detta eftersom gräset på dessa gårdar skördas i större utsträckning.

Nyckelord: Gräsbarriärer, Höglandsodling, näringsförlust, Träjordbruk, Vietnam

Institutionen för växtproduktionsekologi, SLU
Box 7043 75007 UPPSALA, ISSN 1401-5765

II PREFACE

This master thesis is a project covering 30 ECTS. It is the final project in the master´s program in Environmental and Water technology at Uppsala University (UU) and the Swedish University of Agricultural Sciences (SLU).

This thesis was part of an ongoing research project in Vietnam called *Agroforestry for sustainable livelihoods, environmental resilience, and climate change adaptation in Montane Mainland Southeast Asia* (VR Grant number 2019-03740). The project aimed to contribute to sustainable development by evaluating agroforestry practices and systems. This thesis study was carried out with joint support from ICRAF (World agroforestry) in Vietnam, the Soils and Fertilizers Research Institute (SFRI) in Hanoi, SLU, Uppsala, and the Department of Agriculture and Rural Development Offices in Dien Bien and Son La provinces. It was funded by the Swedish Research Council VR and through a minor field study scholarship.

The supervisor of the thesis was Sigrun Dahlin, Associate Professor at the Department of Soil and Environment at SLU. Professor Ingrid Öborn, Department of Crop Production Ecology at SLU, was the academic supervisor.

The thesis research was carried out on smallholder farms where agroforestry practices had 2015 been established on sloping land as part of the AFLi-funded project, which was led by ICRAF. The majority of the data used was collected as part of the ongoing VR -project. The chemical analyses of plant and compost samples were carried out at SFRI, Hanoi.

UPTEC W 20XXX, ISSN 1401-5765
Published digitally at DiVA, through Department of Earth Sciences, Uppsala University, Uppsala 2023

III POPULÄRVETENSKAPLIG SAMMANFATTNING

Vietnam är ett av världens mest tätbefolkade länder, vilket innebär att det finns ett stort behov av att utnyttja landmassor för jordbruk. Stora delar av landytan består av berg, vilket medför att en större andel av fälten är lokaliserade i branta sluttningar. I dessa områden är erosion ett stort problem. Den huvudsakliga mekanismen till att erosionen sker är de kraftiga regnfall som marken utsätts för till följd av Vietnams geografiska placering. Erosionen för med sig både landmassor i form av jordpartiklar, samt bidrar till att utarma jorden på näring. Näringsutlakning från jordbruksmark är ett av de största problemen inom odling, och bidrar till lägre skördar för jordbrukarna. För att minska näringsläkaget tillämpas näringshanteringsprinciper så som precisionsodling. Det är nämligen inte bara erosion som bidrar till näringsförluster, utan även allt för stora gödningsgivor. Utöver precisionsodling tillämpas även olika odlingssystem för att minska erosionen och näringsutlakningen, så som agroforestry (eller trädjordbruk) och horisontella gräsremsor som stoppar jorden från att röra sig nedåt. Agroforestry innebär att jordbruk av grödor kombineras med odling av träd och i vissa fall även med djurhushållning på fälten.

Under år 2020 skrevs en masteruppsats om hur erosionen kan minskas genom odling av gräsremsor horisontellt längs med fältets sluttning. Syftet med denna masteruppsats är dels att följa upp den tidigare masteruppsatsen från 2020 och undersöka hur dessa gräsremsor kan bidra till att fånga upp den näring som övriga växter i odlingssystemet inte hinner ta upp, och som annars skulle lakas ut och hamna i den omkringliggande miljön. Utöver detta undersöktes näringsbalansen på gårdarna ur ett helheltsperspektiv (per gårdsnivå) samt inom gårdarna (per fält). Även näringsförlusten under gödsellagringen undersöktes. Studieobjekten var tio gårdar i nordvästra Vietnam.

Resultat togs fram genom att samla in information från jordbrukarna i området. Insamlingen gjordes med hjälp av intervjuer, samt genom att besöka odlingarna och se hur de tillämpade systemen ser ut i dagsläget. Utöver detta samlades gräsprover och gödselprover in för analys. Gödselproverna analyserades på kväve, fosfor och kalium, medan gräsproverna analyserades på koncentrationen av kväve i det gräs *(Panicum maximum Jacq.)*, här kallat guineagräs, som odlades på fälten. Detta gjordes för att kunna kalibrera den SPAD-meter som användes för att samla in data på kvävevärden gräset. Resultatet visar på att det gräs som används för att minska erosionen bidrar till att minska accumuleringen av N, P och K på fälten. Resultatet indikerar även att gräset absorberar så mycket kalium, att övriga grödor riskerar att få kaliumbrist.

Totalt sätt visar resultatet på att gräsremsor är en effektiv form av erosionshinder, då det även absorberar delar av den näring som annars försvinner med ytavrinningen, men att det i detta fall behöver kompenseras med mer kalium-baserat gödsel. Generellt syns mönster av övergödslande med kväve och undergödslande av kalium. Resultatet visar även att detta system fungerar effektivt i de fall där gräset används som fodergräs och därmed skördas regelbundet. I övriga fall tenderar gräset att sprida sig utanför de planterade gräsraderna. Dessutom forslas inte överskott av näringen bort från fältet, utan stannar kvar i gräset. På så sätt kommer näringen till användning. Till sist visar arbetet på att gårdarna förlorar signifikanta mängder kväve, fosfor och kalium på grund av ineffektiva lagringsmetoder för gödslet.

IV ACKNOWLEDGEMENT

Many thanks to my supervisor, Prof. Sigrun Dahlin, for the support and guidance during the writing of the thesis, but also during my stay in Vietnam as well as the during the application for the minor field study grant. I also want to thank my local supervisor in Vietnam, Dr. La Nguyen for all the help during my stay in the field, and for showing me around and introducing me to the farmers involved and the study area. Furthermore, I want to thank Prof. Ingrid Öborn for her valuable input regarding the presentation of the project. A special thanks to Mr. Thuong Pham Huu for all the help during my first weeks in Hanoi, for organizing the permits needed for the field research, and providing me with useful data and tips for the analysis and gathering of data.

I also want to give a big thanks to my translator in the field, Mrs. Hoài Nguyen who assisted me with help during the field visit as well as during my time in Hanoi. Additionally, I want to thank Dr. Phai for assisting me with the analysis of compost and grass samples.

A big thanks should also be given to all of the staff members at the ICRAF office and SFRI, who welcomed me to Hanoi and made my time in Vietnam easy and fun.

Last but not least I wish to give a huge thanks to the farmer families in Son La and Mrs. Lo Thi Quyen, the local agricultural extension staff in Hat Lot commune, Son La, who helped us find farmers we could interview, for their help gathering data and for their hospitality during the surveying.

To have been given the opportunity to participate in a project like this one has been great. The experience in the field as well as in the office in Hanoi has taught me many things, given me precious memories to keep, and helped me expand my own comfort zone.

Contents

5 Introduction

The project site is located in Hat Lot commune, Mai Son district in Son La Province, in northwest Vietnam. The size of Vietnam is 331 114 km^2, and it has a population of about 97 336 000 people (Daleke, 2021). In comparison to Sweden, Vietnam has approximately 10 times more inhabitants per square kilometer, which increases the need for efficient land use. Approximately 40 % of the workforce is employed in agriculture and around 25 % of the land is agricultural land. The farmed land equals approximately 0,07 % hectare per person, which is one of the lowest numbers in the world. Due to the high demand for food, the pressure on the land is high and the land is often over-exploited (Daleke, 2021).

Son La Province has an annual rainfall of about 1430 mm with 85 % concentrated between April and September (the growing season). The elevation ranges from 100 to 2,900 m, with 92 % of the province being hilly and mountainous and 67 % occupied with slopes with a gradient over 15 %. As a result of the diversified elevation farmers is forced to cultivate lands with steep slopes even over 25 % inclination. As a consequence, soil erosion has increased, exacerbated by heavy rainfall events. In addition to the loss of bulk soil, this also leads to large losses of plant nutrients.

Soils naturally contain large amounts of plant nutrients such as nitrogen, potassium, and phosphorus. However, only a small fraction is immediately plant-available, so farmers usually add additional nutrients using different kinds of mineral or organic fertilizers. Soil erosion contributes to the movement of sediment away from the farming area and into nearby streams. This leads to eutrophication of water bodies, muddy flooding of roads, and sedimentation in streams (Nguyen & Pham, 2018). Nutrient leaching also occurs without erosion. When the nutrient supply exceeds the amounts the vegetation can take advantage of, the surplus nutrients are flushed out to nearby ditches, streams, and groundwater. Eventually, this leads to algae blooming and anaerobic conditions on the bottom of water basins, similar to the effects of erosion (Jordbruksverket, 2020). Nutrients are a limiting factor within agriculture and in the highlands of Vietnam, the loss of nutrients occurs from both erosion and leaching due to soil losses and surplus nutrients. By using existing resources more effectively, livelihoods of the farmers would improve.

The population in the high mountains of the Son La province belongs to the poorest population in the country. Among the reasons behind this is the high frequency of minority groups in the region (WorldBank, 2022) and the infertile soils of the steep slopes. A previous project in the same area *Agroforestry for Livelihoods of Smallholder Farmers in Northwest Vietnam* (AFLi) was carried out in two phases during 2011-2021 in Northwest Vietnam. The study researched, among other things, how smallholding farmers could improve their yield and economy by using agroforestry techniques (La et al., 2019). The exemplar landscape was established in 2015. This thesis is following up on ten of the farms within the exemplar landscape and looks at nutrient management within the farms. The thesis was made possible due to already established contacts and cooperations with the farmers in the province. This contact was established during the AFLi - project.

Previously, a master thesis on erosion control was made in this area ((Thelberg & Sjödell, 2020)). The thesis examined the use of grass strips as a means to create natural terrace formation and thus work as an erosion control (Thelberg & Sjödell, 2020). This was of interest as the method is considered a cost-efficient way to prevent or reduce erosion. The method proved to be working efficiently to reduce erosion. The result of the study showed that the soil loss was reduced by 43 % after two years in comparison to the fields without grass strips (Thelberg & Sjödell, 2020). The grass used for the grass strips was guinea grass. Guinea grass can be a good fodder grass, but the nutrient content of the grass varies depending on the nutrient supply in the soil (Varghese Jose & Nabi, 2022). Whether the grass strips could efficiently capture eroded nutrients was not tested in 2020. One aim of this study was to follow up on the grass strips and estimate whether they take up considerable nutrients from the soil and by doing so prevent the nutrients from being lost through erosion, leaching, or surface runoff. The thesis focuses on the nutrient flows on ten farms within the project site in northwest Vietnam (Son La). A farm gate balance as well as the field and homestead balances were calculated to locate sources and sinks of nutrients.

5.1 Main objectives and research questions

This Minor Field Study looked at the impact on the nutrient flow by replacing conventional mono-cropping with agroforestry systems with and without grass strips planted along the contour. The overall aim of this study was to locate and quantify sources and sinks of nutrients within the ten chosen farms. By identifying these locations, higher precision in the farm's nutrient management may be achieved, leading to higher nutrient use efficiency, lower nutrient losses, and enhanced farm productivity and better livelihoods.

To reach this aim two specific objectives were looked into. These objectives were:

1. Create a farm gate balance of nutrient inputs and outputs to the farm following the cash flows. Inputs such as purchased feed and purchased mineral and organic fertilizers and outputs such as sold crops, animals, and other products were used. The flows are expressed as kg/ha i.e divided by the area of the farm. This will give an overall idea of nutrient surplus and deficit and environmental risks.

2. Quantify the on-farm flows and balances of nutrients. On-farm flows will be examined by looking at the compost handling i.e the manure storage and each field individually (field balances). Field balances are calculated using fertilizers as input and harvest as output. Nutrient balances during manure storage are calculated using feed and material added to the compost as input and produced compost and sold or slaughtered animals as output. This will give an indication of the locations of the sources and sinks within each farm. Additionally, it will show if the grass strips help absorb nutrients lost through erosion.

Research Questions

- Could grass strips contribute to significant nutrient uptake and decrease the risk for nutrient loss?
- Within farms practicing agroforestry, where do the nutrients accumulate?
- In which areas on the farm does nutrient mining occur?
- Is there a significant loss of nutrients during manure storage?

Hypotheses

- Grass strips along the contour capture nutrients lost from the plot area above, which decreases the overall loss of nutrients (hence decreasing the risk for eutrophication in nearby streams) and supports high grass production and protein content in spite of no direct fertilization.

- Nutrients accumulate downslope, i.e in the lower-lying parts of the farm. As a consequence of harvesting fodder grass up the slope, but using the compost on downslope fields, the cycle of nutrients is disrupted. The accumulation of nutrients downslope leads to unnecessary nutrient losses.

- Nutrient losses from the manure storage are at least as big as the nutrient export via farm produce

5.2 Delimination

This thesis will only look at the nutrients nitrogen, phosphorus, and potassium. The research does not look into economical aspects such as the income from the crops, fruit trees, or the selling of animals. Nor does it consider the cost of farming at the different farms, such as the cost of fertilizers, etc. The gathered information covers one year of production data and thus covers the time between September 2022 and one calendar year back in October (2021). Human waste (kitchen waste and toilet waste) is excluded from calculations. Measurements of nitrogen in the grass were only made on the grass strips located on the bottom part of the fields.

5.3 Explanation of words and designations

Since the thesis is carried out in another country, the use of words differs, as the meaning is not always consistent. This wordlist will explain the meaning of some commonly used words.

Compost = A more or less decomposed manure. Manure is set aside to be metabolized by microorganisms. The result is an odor-free compost with few or no pathogens. The compost can also contain added (decomposed) organic materials such as crop residue.

Organic kitchen waste = leftover organic material from the farmhouse.

Closed system privy = Privies with brick-constructed pits. The system is closed and the pits are emptied (by municipal latrine emptying) when full.

home garden = the vegetable garden located in direct proximity to the house. Included in the home garden are also in most cases fruit trees.

Homestead = The house of the farmer family and the stables.

Nutrient losses = nutrients that have been lost due to evaporation losses, leaching, or due to runoff water.

Nutrient accumulation = Occurs when the nutrient depot in the soil is greater than the plant need.

Nutrient depletion or mining = Occurs when plants use the nutrient depots for a longer time and when no or insufficient nutrients are supplied to make up for the plant-absorbed nutrients.

Export = The flow of nutrients through sold products (products leaving the farm).

Import = The flow of nutrients through bought products (products entering the farm).

In the calculations, nutrient content refers to the content of N, P or K. The following variables were used:
N = Number of harvesting days
G_m = kg harvested grass
C_n = The concentration of nutrients in the material n
Q_n = The mass (kg) of a material n
I_f and O_f = Inflow and outflow of kg N (Nitrogen), P (phosphorus), or K (potassium) on the field
$I_{Homestead}$ and $O_{Homestead}$ = Inflow and outflow of kg N, P or K to the homestead
$I_{Farm-Gate}$ and $O_{Farm-Gate}$ = Inflow and outflow of kg N, P, or K at the farm-gate
M = kg nutrient content in the mineral fertilizers (always bought)
V = kg nutrient content in the used compost
V_S= kg nutrient content in the sold compost
V_B = kg nutrient content in the bought Compost
Fr = kg nutrient content in the harvested fruit
Fr_S = kg nutrient content in the harvested sold fruit
Cr = kg nutrient content in the harvested crops
Cr_S = kg nutrient content in the harvested and sold crops
G = kg nutrient content in the harvested grass
G_S = kg nutrient content in the harvested and sold grass
R = kg nutrient content in the collected residues
Fo = kg nutrient content in the harvested fodder given to the animals (includes all fodder harvested on the farm)
Co = kg nutrient content in the concentrates given to the animals (includes all bought manufactured feed)
H = kg nutrient content in the household food (include all food consumed by the farm holders)
H_B = kg nutrient content in the bought additional household food (e.g rice, meat, fish)
A_S = kg nutrient content in the sold animals
A_B = kg nutrient content in the bought animals
A_{SS} = kg nutrient content in the total of sold and deceased animals

6 Background

6.1 Plant nutrient need, supply, and losses

Plants grow and develop as a result of many complex processes, including the utilization of plant nutrients. Plant nutrients are divided into micro- and macronutrients, of which the macronutrients are required in higher amounts. Among the macronutrients, the primary nutrients are nitrogen (N), phosphorus (P), and potassium (K). Some of the usages of N in plants are to build proteins, amino acids, and chlorophyll in plants. Phosphorus is, among other things, required for the synthesis of protein, and K are needed for water regulation and enzyme activity, etc. A deficit of nutrients leads to lower plant yield. Additionally, excess nutrients threaten to disrupt the ecosystem as they cannot be absorbed by the plants but instead leaches into the surrounding environment. When fertilizers are applied outside of the growing season the effect is the same as when adding too many kg of fertilizers. One of the effects of nutrient leaching is eutrophication (in the case of N and P) (Varghese Jose & Nabi, 2022).

To meet the nutrient needs of the crops, minerals as well as organic fertilizers (such as manure or composted crop residues) are used to fertilize fields. Insufficient fertilizer use and efficiency on farms have historically contributed to low agricultural yields (Varghese Jose & Nabi, 2022). To be able to maintain good nutrient management it is important to balance the in and outflows of plant nutrients on the farms, as well as to establish sustainable farming practices. Sustainable farming practices include other than nutritional issues (Bergström & Dahlin, 2005). When nutrient management is practiced, the idea is that farmers add, by the plant, the correct amount of nutrients needed at the right time. This is often called precision farming. It is believed to not only be beneficial for the environment as fewer nutrients will be lost but also produce a higher yield (Bergström & Dahlin, 2005). If the use of nutrients is made more efficient, food safety will be improved in many countries, and the number of excessive nutrients released into the environment will decrease (Varghese Jose & Nabi, 2022).

Animal keeping and thus manure production on the farm is valuable for production of crop and fruit. When manure is used to produce organic fertilizer it returns some of the nutrients taken up by plants to the soil and a sustainable nutrient cycle is established. This is the case given that the animals graze or feed from materials grown on the farm. If the farm does not house animals, nor buy manure from other farmers, crop residues can be used to recirculate nutrients to the soil (Bergström & Dahlin, 2005) to reduce the need of buying mineral fertilizer.

Using compost as a fertilizer has both advantages and disadvantages. Some advantages are that the compost contributes additional nutrients (apart from N, P, and K) as well as organic material that has a positive effect on the soil's physical conditions (Celik et al., 2004). A disadvantage is that the compost is heavy and bulky, and it is therefore unevenly distributed around the farm. This contributes to variation in fertility among the different compartments on the farm. Nutrient losses may occur during storage. The losses are determined by the design of the storage, and if the manure and compost is covered or not. If the manure and compost are not covered, the rain will cause additional nutrient losses (Tittonell et al., 2010). Due to this, it is good to make a farm-specific nutrient balance to decide where the major nutrient losses occur within the farm.

Plant nutrients are, as mentioned, lost from the fields through various routes. However, the main mechanisms are surface runoff and leaching. When runoff occurs there are two ways in which it contributes to nutrient loss. The first way is when applied nutrients dissolve into the soil solution. Soil nutrients then leave the soil through the surface runoff water due to water exchange. Soil nutrients also enter runoff water through desorption from soil particles or through sediment transportation, adsorbed on the surface of the soil particles. Nutrient losses are affected by rainfall intensity. Higher losses occur as the rainfall increases. It is also affected by the water flow (with higher losses occurring with a higher inclination and less friction) as well as vegetation cover and farming methods (Yao et al., 2021). As the farmland in the researched area has both intense rainfall and a steep slope, increased vegetation cover and agroforestry methods such as horizontal grass strips and fruit trees have been introduced in the fields to prevent the runoff flow and thus the erosion and nutrient losses (Rachmat & Nguyen, 2022). As farmers add mineral or organic nutrients to a sloping field, the risk is that much of the nutrients leave the soil with runoff water before the plants can absorb them. This especially occurs during the early farming season as the plants are still small (Al-Kaisi & Helmers, 2008; Bergström & Dahlin, 2005) and the rain can be heavy.

6.2 Erosion control

As the size of the population increases, so does the scale of conventional farming and modern forestry. As these two huge industries require more land for their production, the consequence is evidently deforestation. As forests are cleared the productive capacity of soils declines, erosion accelerates, siltation of dams and reservoirs occurs, biodiversity decreases, and the wildlife habitat is destroyed (Nair et al., 2021).

There are many methods used to decrease erosion. Among these, some commonly used are contouring, terraces, and water and sediment control basins as well as strip cropping. When constructing man-made terraces the gradient of the soil is changed to give the field a horizontal, instead of a sloping, surface. This construction breaks the water flow downslope so that rainwater or irrigation water is held on the field and thus infiltration to the soil increases. A waterway is constructed to lead the excess runoff water safely away from the slope in a way that prevents erosion from occurring i.e by ensuring that water outlets are vegetated. A problem with this technique is that the water that is led away from the field is also being lost (Truong & Loch, 2004).

A way to bypass constructed terraces is to grow grass strips along the slope contour. The vegetative barrier creates a protective barrier alongside the contour. During rainfall, the water transports sediment to the grass strips, where the runoff water is slowed down, and the sediment is deposited. Within a couple of years, small terraces have naturally formed (Truong & Loch, 2004). In addition, the grass strips also capture potential contaminants and/or pesticides (Hoekstra & Hannam, 2017). A research study within the exemplar landscape showed that terraces formed as the systems developed, through the gradual deposition of soil sediment above the living grass strips and trees. After the five-year study period, the study could identify a 4.0 cm raise in soil surface due to accumulated soil sedimentation above the grass strips. On average N, P, and K losses decreased with 21 - 84 % (Do et al., 2023) Another study showed that after only one to two years the eroded soil had started to form natural terraces on the slope (Thelberg & Sjödell, 2020). Lastly, a two-year-long study made on sloping sole maize fields in the US showed that the N, P and K losses decreased by 78 %, 77 %, and 68 % after adding a 3 m grass strip to the maize field compared with fields without grass strips (Maass et al., 1988). Additionally, the grass can for example be used to feed animals. This way contouring grass strips contribute to decreasing erosion, increasing water infiltration, and producing fodder grass. Finally, no land is wasted on waterways.

Out of these methods, terraces and control basins are the more efficient methods when severe soil erosion occurs (Czapar et al., 2005; Truong & Loch, 2004). However, neither terraces nor control basins are cost-effective. On the contrary, the methods are not only expensive due to the need for an accurate and detailed design but are also labor intense and in need of regular maintenance. The prices of constructing terraces with vegetative outlets have been reported to be more than five times more expensive than the use of contouring farming (Czapar et al., 2005; Truong & Loch, 2004). Although prices have changed since then, low cost-efficiency is still a problem when constructing terraces. As the population in the high mountains of the Son La province belong to the poorest population in the country, the cost of constructing terraces becomes a limitation (Thelberg & Sjödell, 2020). Due to this, the use of contouring grass strips is a good choice in the area.

Figure 1:
Grass is planted in rows along the contour.

6.3 Guinea grass as a measure for multiple benefits

Fodder grass is used to feed animals such as cow, buffalo, goat, and fish. What makes the contribution of fodder grass to agroforestry systems smart is its double effect. While it provides feed for the animals, it also works as a means to prevent erosion from occurring.

The fodder grass used on the test site in Mai Son is guinea grass (Rachmat & Nguyen, 2021). Guinea grass is a good choice economically due to its excellent traits as a fodder grass (Rhodes et al., 2021). The grass is especially good in the cut-and-carry system used on the test site, as well as due to its rapid ground cover that helps prevent erosion. The N concentration in the guinea grass varies dependent on the nearby conditions. In the open the N concentration of guinea grass is 0.55 %, while under vegetative cover the N concentration is 0.72 % (Amar, 2012).

6.4 Agroforestry

6.4.1 Definition(s) and meaning of agroforestry

The word agroforestry is a merge of the two words agriculture and forestry and as it suggests, a practice that could be described as somewhere on the line in between. So far the meaning is clear. However, there are many ways to practice agroforestry (Nair et al., 2021). Over a hundred different agroforestry systems with similar practices have been found across the world (Atangana et al., 2014). The practice of agroforestry is as wide as the practice of agriculture. This is of importance as the word is often confused as a synonym for alley cropping or permaculture (Nair et al., 2021).

Originally the practice of agroforestry was mainly food production and in some places a means to restore forest production, although not in the same way as of today (Nair et al., 2021). Today (since the term was coined in 1977), the term agroforestry has widened to include the conservation of biotopes and soil fertility among other things. It is often described as a system involving two or more species of plants on the same management unit, of which at least one is woody perennial, with a harvest of more than one species and a system cycle lasting for more than one year. The outcome is a practice focused on diversified farm production, sustainable crop yields, and the realization of ecosystem services. It should be stressed here, that there is no equal sign between agroforestry and sustainability if one does not understand the overall system. For agroforestry to be a more holistic choice than other forms of land use, the practitioner must understand the management principles and maintain the system (Nair et al., 2021).

As the research area is new (since the 1970th), several studies have been carried out to identify the difference between conventional farming and agroforestry. In conventional agriculture trees and/or bushes do not play a part. In conventional forestry crops or animal production is not present. In agroforestry, the system includes both trees or bushes and crops, and in some systems also livestock. The growing of trees with crops and/or animals should be an intentional combination that interacts to provide several products, benefits, and/or usages (Atangana et al., 2014).

The purpose of agroforestry varies slightly depending on where in the world it is practiced. In temperate zones, (between the Tropic of Capricorn and the Antarctic Circle in the southern hemisphere as well as between the Tropic of Cancer and the Arctic Circle in the northern hemisphere), the main motivation for adopting an agroforestry system is the environmental benefits. Reduced climate change through carbon storage, improved water quality, and increased species diversity are key factors. In the tropics, (23.5 degrees south and north of the Equator (including Vietnam)), the focus is mainly on food security. Agroforestry is mainly performed on smallholder farms or community land where land is used to produce food for the family and/or the local market (Nair et al., 2021).

7 Nutrient balances

Nutrient management is important from a natural resource perspective but also because of its economic value (Öborn et al., 2005). A case study on animal farms has found indications on that improved nutrient management can lead to less nutrient losses while still generating improved animal production (Dahlin et al., 2005). In the EU a study of the nutrient balance was made on dairy cows. The nutrient balance calculations made in the study showed that the inputs of nutrients (in terms of bought fodder) greatly exceeded the outputs (animal products). The nutrient outputs were equivalent to only 30 % of the nutrient inputs in the production (Watson et al., 2008). Nutrient balances, such as for N, P, and K, can be used as a tool to reduce nutrient emissions from agriculture to the environment (Öborn et al., 2003). Nutrient balances are calculated as the difference between the inflow and outflow of nutrients.

When looking at the nutrient management on a farm it is not enough to only look at the overall in- and outflows of nutrients on the farm (the farm-gate balance). Nutrient management requires that the flow of nutrients within the farm, and even within each field, is considered (Bergström & Dahlin, 2005). To create an elaborate model nutrient balance calculations can be made on several parts of the farm system. A homestead balance (inflows to the homestead - outflows from the homestead) and a field balance (inflows to the field - outflows from the field), account for both internal and external flows. These two, combined with the overall farm-gate balance, can give a better understanding of the sinks and sources within the farm system (Öborn et al., 2005). The calculations used to quantify sinks and sources of nutrients can be seen in section 8.

8 Materials and Methods

8.1 Site description

8.1.1 STUDY AREA

The area of northwest Vietnam is characterized by its sloping landscape. The area covers 5.64 million ha and 87 % of this area has slopes of 25 % degrees or greater (Hoang et al., 2017)

8.1.2 Study sites

The study site is referred to in the text as the exemplar landscape. The exemplar landscape is an area of 50 ha, located in Na Ban village, Hat Lot commune, Mai Son district, Son La province. At the study site, the farmers practice agroforestry. The main system of agroforestry consists of a combination of fruit trees, maize, and guinea grass *(Panicum maximum Jacq.)*. The grass is strip planted along the contour lines. Longan *(Dimocarpus longan Lour.)*, mango *(Mangifera indica L.)* or plum *(Prunus domestica L.)* is generally grown in rows with 15 m apart each row. Half a meter down the slope from the fruit tree row are two rows of guinea grass and in the remaining area, maize is grown. However, variations of this design have been implemented on different farms. The ecological benefits are reduced soil erosion due to strips of fodder grass along the contour lines and carbon sequestration etc (Rachmat & Nguyen, 2022).

Figure 2:

Grass is planted in as contour lines, beneath the tree line. Crop residues from maize can be seen beneath the grass rows.

8.1.3 Climate

The area in northwest Vietnam has a subtropical climate with seasonal rainfall. The wet season is between April to October and the dry season is between November and March. 21.5 degrees is the mean annual temperature. Annual precipitation is generally between 1200 to 1600 mm (Do et al., 2023).

The fieldwork was carried out in two periods. The first period was between 27 September and 9 October (2023) whilst the second period took place between 24 - 28 October. During the time of the field study, the weather was hot, sunny, and dry. No rain events occurred during fieldwork.

8.1.4 Selection of study farms

The farms that were interviewed were selected by Mrs. Quyen, the local agricultural extension staff in Hat Lot commune, Son La. All farms were chosen on the premises that they would have similar sizes and be located within the exemplar landscape. Among these, five farms with cows or buffalos, and five farms without cows or buffalos were chosen. The reason for this distinction to the large amount of grass that the cows or buffalos consume. If the farm has cows or buffalos or not will impact the use of fodder grass on the fields, and thus the nutrient flows.

8.2 Interviews

To gather the raw data used in this thesis structured interviews were carried out. The interviews were anonymized and carried out with the help of a questionnaire which can be found in Appendix A. The questionnaire was constructed using a methodological triangulation method. It contained quantitative questions for the farmers. These questions regarded the quantities and materials of fertilizers, harvest, animal feed, compost, and household food. As an example, the questionnaire asked what type of plant the farmer grew. The follow-up questions were: what type of (and how many kg of each) fertilizers the farmer used on that particular plant; how many kg of that plant had been harvested during one year and what was the use for the harvest. Similar questions were asked about the habits of the animals. These questions focused on asking what type of animals lived on the farm; what type of feed these animals were fed; where the feed came from and how many kg feed they were given each day; the quantities of their droppings and how many of the animals that were sold, slaughtered or deceased during one year. Additionally, a qualitative part was added, where the interviewer noted down the construction of the manure storage. The qualitative part of the interview also contained pictures taken by the interviewer and descriptions of the field systems within the farms. The purpose of gathering this information was to get the quantities of all organic materials that were relocated within the farm. This information was used to construct nutrient balances on the fields and the farm and to calculate nutrient losses during manure storage.

Interviews were carried out during the two field visits to Son La province in September and October 2022. The interviews gathered information from October 2021 until September 2022 needed to estimate and visually understand the nutrient flows within the farms. The farmers and Mrs. Lo Thi Quyen, our local agricultural extension staff, were very helpful. Not only did they take their time to be interviewed, but they also showed us the fields although they in many cases were located more than a kilometer from the house and required a vehicle to reach. They always gladly invited us into their homes and helped us gather the information we needed.

The interviews were made with the help of a translator Mrs. Hoài Nguyen, who translated the survey into Vietnamese and the answers into English. As the way the farmers presented their data varied between farms, different methods to calculate and estimate the average nutrient flow had to be used. To increase the robustness of the result more than one type of calculation was made when this was possible. The average value conducted from these methods was then used. During the interviews pictures of the fodder bags and fertilizer bags were taken to collect information regarding the nutrient concentrations in the bags. The concentrations of the bags was then translated with the help of SFRI and ICRAF staff.

8.3 Collection of compost and nutrient analysis

In addition to buying mineral fertilizers, the farmers use organic fertilizer (compost) from their farms or bought. The compost consists of composted manure with or without added materials such as rice straw or macadamia peel. To determine the nutrient concentrations, samples from the different types of compost were collected from the farms. Only compost ready to be used was collected. In some cases, the compost samples could not be collected as they had recently been used for the fields, or were not ready to be used yet. The compost was collected by the farmers upon clear instructions to stir the pile of compost and then take several samples from different parts of the pile. The compost was stored in double plastic bags with zipper locks and transported to the SFRI lab in Hanoi. Each sample was divided into two samples. One part of the sample was weighed, dried, and weighed again to calculate the water content. The other part was analyzed for N, P, and K concentrations. For the cases where no samples could be collected an average value was used. The average value was based on the analyzed samples from the same type of animal on the other farms. For the samples with crop residues added, literature values were used to calculate the N, P, and K concentrations of each component (of crop residue) in the compost. The concentration in each component was multiplied by the component weight and the total nutrient content was calculated by summarizing all components. Nutrient concentrations in fertilizers used were found on the fertilizer bags on the farms. To simplify the reading the fertilizers are henceforth referred to with their N, P and K ratios stated in Table 20 in Appendix B.

8.4 NPK values used to calculate the nutrient balance

As earlier mentioned, information regarding the quantities of the relocated organic materials was conducted using the structured questionnaire. Additionally, the N, P, and K concentration of the compost and grass were given by the analyzed samples collected during the field visit. However, all the organic materials were not analyzed in a lab. Due to this, some values have been found through literature research. These materials were, for example, harvested fruits or crops, animal fodder, and sold or deceased animals. Where it was possible, the concentrations were obtained by using the stated values on the package. Some concentrations, such as for grass and maize, came from previous studies in the same area. A complete list of materials and the used N, P, and K concentrations can be found in Appendix B. A standard value was used to convert from protein concentration to nitrogen concentration (ASEAN, 2014). Potassium concentration was not stated on the fodder sacks so this had to be calculated using literature values.

8.5 Calculations used in the report

Nutrient balance calculations rely on data that are readily available at farm-gate and field levels. This makes it a good choice of method for this thesis. The nutrient balances are calculated using the N, P, and K concentrations in the relocated organic materials and their respective quantities. An additional reason to use this method is that it provides information that can easily be given to and understood by the farmers.

8.5.1 Calculation of the area of grass strips, maize, fruit trees, and black beans

In general, the fields were Inter-cropped with two or more components. Information about crop- and row distance as well as the number of trees was collected together with the amount of fertilizer applied to each field and/or crop. In many cases, the farmers were lacking information regarding one or more crops, such as harvested yield or field area for one or more of the crops. To determine the nutrient balances of these fields an estimation had to be made.

During 2022 the harvest within the exemplar landscape was approximated to 0.8 kg / m^2, and 20 kg seeds were used for planting 1 ha [1]. The farmers usually have several fields where maize (among other things) is grown. However, they generally do not know the area of maize on

[1]Thuong, Pham Huu 2022, Ph.D. student, SLU, ICRAF Hanoi, Vietnam

each specific field. In the questionnaire, the farmers would instead state the kg of seeds that they planted. The maize-covered field area was calculated using the amount of planted seeds and the average harvest yield in the exemplar landscape during the year 2022. An average between the two results was used. When the amount of seeds was not given, the area was calculated using the number of trees and the crop or tree distance to approximate the area used for maize cultivation. By knowing the number of trees and area of grass, as well as the area in between the plants, this ”used” area could be subtracted from the total field area. The remaining field area was assumed to be covered by maize.

For fruit trees, the trees were in most cases the same size on average. Most trees were planted in 2015. A difference in size occurred mainly in cases were the trees were much younger than the average. For younger trees (1-3 years), the distance between crops and the closest tree trunk is shorter than for older trees, however, to simplify the calculation all trees were estimated to have the same radius. The distance between each side of the tree to the closest crop was estimated to be 1.5 m, giving the trees a diameter of 3 m [1]. In some cases, the area of the maize and the fruit trees extended the given area of the field when using these estimations. In these cases the trees were either small and/or maize was planted in between the tree rows as well as between the trees within the tree rows. This was not the average method of planting. The general method on the surveyed farms is to plant maize in rows parallel to the tree rows. Therefor the general planting method was used as a reference when making estimations and calculating the approximate area. In the cases where the number of trees were not given, the crop and row distance was used to calculate the number of trees in the field.

The area of black beans was calculated using the given amount of seeds planted, and the literature value from Mogeni, (2020) for the corresponding area. The area of fodder grass was calculated in two ways depending on the given information. The first method was to withdraw the area of additional crops and fruit trees from the total area of the field. The second method was to use the given length of the rows, and the number of rows. The calculation was made based on the estimation that each grass row is approximately 1 m wide. The calculation of farm 3 will be shown as an example of how the calculation was made. The calculation can be found in Appendix C.

8.5.2 Calculation of the number of animals over the year

In Table 35 in Appendix D, as for the equivalent tables for the other farms, the number of animals during the year (October 2021 - September 2022) was specified. Information on the number of animals was collected during the interviews. The number of animals is estimated based on the number of animals on each farm in September 2022 and how many animals were born, bought, or slaughtered, and at what age, during the past year.

8.5.3 Calculation of harvested grass per day and year

In the interviews, the harvest of fodder grass was given as kg harvested per day and how many days of the year the grass was harvested. The average yield per day was calculated according to eq. (1). G_m is the kg of harvested grass and N is the number of harvesting days.

$$Average\ yield\ per\ day = G_m \cdot \frac{N}{365}. \tag{1}$$

However, on some farms, the harvest differed throughout the year. One of the reasons for this is that the grass does not grow during the dry season. Furthermore, at farm 7, there used to be four cows during Oct-Dec last year, that are now sold. The grass is now not used by the farmer itself but cut by the neighbor. In Table 2 the usage is stated as 10 kg per day, given to cows and sold. This is calculated based on the given amount of grass harvested for the cows during Oct-Dec. The grass harvested by the neighbor is insignificant to the calculation.

8.5.4 Calculation of nutrient flows and nutrient balances

Nutrient balances are calculated in accordance with the specific objectives. For the first specific objective nutrient balance is calculated on the farm level in kg/ha for one year. For the second specific objective nutrient balances are calculated for each field individually and given as kg/ha for one year period. For nutrient losses during manure storage, calculations are stated as kg/farm. The calculations account for nutrient losses from manure derived from all types of animals on the farm.

Each category (e.g H, M, etc) contains several types of materials. The nutrient content of all included materials was calculated using the product of the nutrient concentration of the material and the mass of the material in accordance with the example in equation (2), which shows how the nutrient content in H was calculated.

$$H = Q_1 \cdot C_1 + Q_2 \cdot C_2 + Q_3 \cdot C_3 + ...Q_n \cdot C_n, \tag{2}$$

where Q_n is the mass of material n, and C is the corresponding concentration of nutrients in the material. The total kg of nutrient content for the category household food is given as H. The following equations will only include the total kg of nutrient content for each category. With nutrient content, it refers to N, P, and K. Every equation was made separately for N, P, and K.

The nutrient concentration C_n was taken from literature values and values derived from the research area by the ongoing VR project. The values can be found in Table 21 in Appendix B.

The nutrient balance on the whole farm was calculated using two different methods for each farm to confirm the robustness of the calculated values. The first method was to calculate the *farm gate balance*, given by the inflow (eq. 3) and subtracting the outflow (eq. 4). The result of this equation is the result that can be found in Table 14.

$$I_{Farm-gate} = Co + V_B + A_B + M + H_B, \tag{3}$$

where $Co; V_B; A_B; M; H_B;$ are the kg nutrient content in the bought feed (concentrates), bought compost, bought animals, bought mineral fertilizers, and the bought household food respectively. With household food, the text refers to what the farmers family bought, such as rice, meat, fish etc.

$$O_{Farm-gate} = Cr_S + Fr_S + G_S + V_S + A_S, \tag{4}$$

where $Cr_S; Fr_S; G_S; V_S; A_S$ are kg nutrient content in the sold harvested crops (maize, sugarcane, vegetables etc.), fruits, grass, compost and animals respectively.

The balance was calculated using eq. (5). The resulting balance was given in $kg/ha/year$ for each nutrient.

$$\textit{Farm-gate balance} = I_{Farmgate} - O_{Farm-gate}. \tag{5}$$

The second balance, *the homestead balance*, is the balance over the farm area including the house and stables. Inflow was calculated using eq. (6).

$$I_{Homestead} = Co + Fo + H. \tag{6}$$

The outflow was calculated using eq (7).

$$O_{Homestead} = V_S + A_S, \tag{7}$$

where V_S is kg nutrient content in the sold compost and A_S is kg nutrient content in the sold animals.

The balance was calculated using eq (8).

$$Homestead = I_{Homestead} - O_{Homestead}. \tag{8}$$

On each individual field the inflow (I_f) of kg N, P or K per year on each field was calculated using eq (9).

$$I_f = V + M, \tag{9}$$

where V is the kg nutrient content in the compost used and M is the kg nutrient content in the used mineral fertilizers.

The outflow (O_f) was calculated using eq (10). The calculation shows the outflow as kg N, P, or K / year.

$$O_f = Fr + Cr + G + R. \tag{10}$$

The balance was then calculated by eq (11).

$$Field\ balance = I_f - O_f. \tag{11}$$

8.6 Calculations of nutrient losses from the manure

Calculations are, like in the previous section, done similarly for all elements N, P, and K.

The nutrient loss during manure storage for all farms and all animals on the farms was calculated using eq (12).

$$Nutrient\ losses\ during\ manure\ storage = Fo + Co + R - V - V_S - A_{SS}, \tag{12}$$

where R is the kg nutrient content in the crop residue added to the compost, and A_{SS} is kg nutrient content in the sold, slaughtered, or deceased unit animal. The loss is given in kg nutrients per unit farm.

8.7 Determination of the N concentration in the grass

To estimate the nitrogen concentration of the grass a chlorophyll meter SPAD (soil plant analysis development) 502 was used. The SPAD 502 calculates a numerical SPAD value that is proportional to the amount of chlorophyll by measuring the spectral absorbance in two wave bands (blue and red) (Konica Minolta, 2009). This can be done due to the mathematical relation between the concentration of nitrogen and the SPAD value shown in figure 3. Figure 3 shows the calibrated relation between the 2nd leaf SPAD value and the shoot N concentration that was obtained in the grass on the fields. This calibration was used to estimate the N concentration in the remaining grass strips.

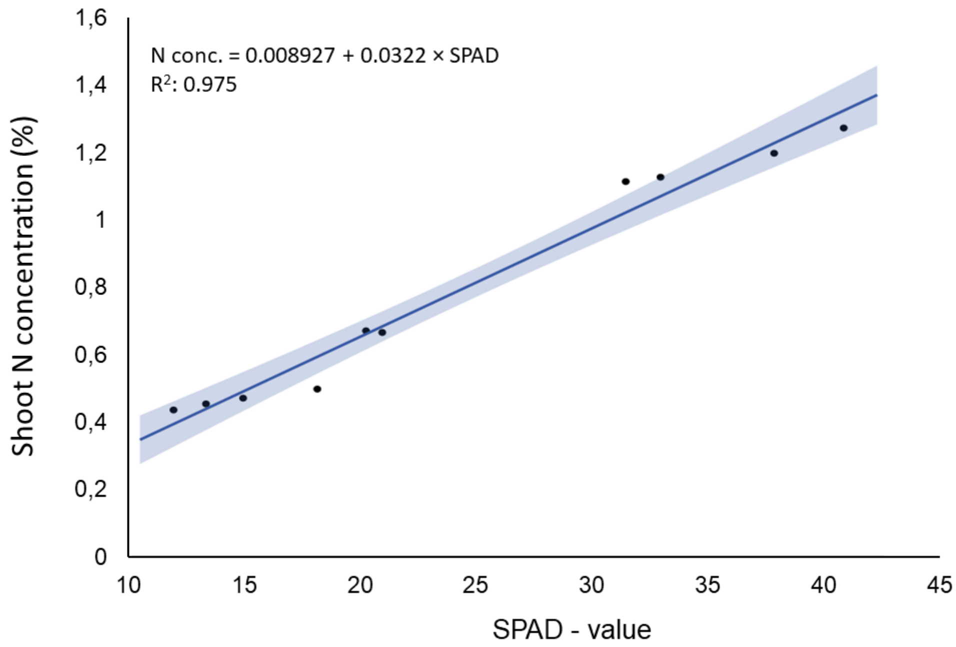

Figure 3: The graph shows the correlation between the SPAD value of the second leaf and the nitrogen value in the harvested part of the plant. This graph was used to determine the N concentration of the harvested grass in the studied fields. The SPAD meter gives a numerical value by pressing the leaf between the two "thoungs" of the handheld light meter. This value is represented as the x-axis in the figure. The y-axis in the figure was determined by analyzing the N concentration of the leaf samples in a lab. Courtesy of H.T.Pham, ICRAF Vietnam

The calibration of the SPAD 502 was made on four fields with guinea grass. The fields were chosen due to their variance in the greenness of the leaves. Ninety samples were collected; light green leaves, dark green leaves, and yellow-green leaves. SPAD measures were made on leaf numbers two, four, six, and eight (depending on the number of leaves per shoot). On each leaf, SPAD measures were taken in the middle of the leaf and a quarter from the top and bottom of the leaf. The average value was noted. In addition to the evenly numbered leaves, the additional leaves (nr one, three, five, and nine) were collected in separate bags after measuring the SPAD value. The stem above the harvest level and the stem beneath the harvest level were collected for ten samples. Before bringing the samples to the lab they were dried in an oven at 50 degrees until no change in water content. At the lab, the samples were divided into groups with narrow ranges of SPAD values, and the leaves and connected stalks were analyzed chemically for their N concentration. The data from leaf number two was used to construct the calibration curve. The reason was that the second leaf data gave the strongest relationship.

8.7.1 Measuring method of the SPAD meter

Through using the calibrated equation in figure 3 [1], the N in the grass strips was measured by using the SPAD meter. To determine the SPAD values on the farmers' fields, the measurements were made on the second leaf (second newest leaf) of the plant. The grass was measured at ten or

[1]Thuong Pham Huu, 2022, ICRAF

eleven different spots at the bottom row of the field. The color of the following rows (on a higher elevation) was checked, and if the color varied, additional SPAD values were taken on these rows. SPAD measures were taken on each field that contained guinea or elephant grass. For fields containing elephant grass the calibration curve for guinea grass was used as an approximation. At the farms where all the crops were given the same amount of fertilizer, SPAD measures were only carried out on one of the fields. Outliers (values >55) were erased during the fieldwork and replaced with a new measure value. This happened about once per field.

9 Results

9.1 Overall description of the farms

Table 1 shows the general outlook of the farms within the exemplar landscape. The households include 2 – 7 people. The farm areas range between 0.6 ha to 3.2 ha and the average size is 14 909 m^2. The variation in size is mainly due to large fields of sugarcane at some farms. The households buy rice, meat, and/or fish and sometimes vegetables as a complementary food. In four out of ten farms, organic kitchen waste is used on plants. In other cases, organic kitchen waste is burned or picked up by the garbage collector. Except for two farms, all farms have a septic tank in the privy, so the system can be considered closed.

Every farm has chicken. Except for chicken, there are seven farms with pigs, five with cows, three with ducks, two with buffalos, and one with goats. The maximum number of each animal type on a farm range between one to five buffalos, one to three pigs (excluding piglets), two to four cows, and 26 to 140 chicken. The only farm with goats had nine of them. Two farms had three and 17 ducks respectively, while Farm 9 stood out with a total of 1000 ducks. Animals are normally not sold. Ducks are only sold for profit at Farm 9. Chicken is normally slaughtered each month for the family to eat. Two farms had fishponds with fish.

Each farm grew mango, longan, forage grass, maize, and vegetables. In addition, some commonly seen crops, fruits and nuts were sugarcane, plum, macadamia, pomelo, and dragon fruit. Rice, coffee, banana, pear, lemon, soybean, and black bean occurred on one to two farms each. Generally, maize and vegetables were used on the farm, while fruits, beans, sugarcane, and nuts were sold. When the harvest was small, the products were generally used on the farm only. Banana was only used to feed animals. Lemons were only used for the household. The grass is used on farms with cows, buffaloes, fish, or goats. In the farms without grass-feeding animals, the grass is given to the neighbors or sold. This year all the farms faced low temperatures during the December - February season, resulting in low yield from the fruit trees.

After pruning the fruit trees, bigger branches are brought to the farm to burn for cooking. Small branches are left on the field. The most common practice is to scatter them around the trees. Maize residue is always left on the field. In the case of sugarcane, the crop residue is generally given to the animals as feed. Rice residue is used in the compost or as feed to the animals.

Compost made from chicken manure was only used in the vegetable garden while pig-, cow, buffalo, and duck manure was used on crops and trees. At farm 1 and 3 rice straw, rice husk, or macadamia peel was added to the compost. The compost was then stirred every 15 to 20 days.

On the other farms, no crop residues were added and the compost was stirred a maximum of one time at the start (table 3). It was clear that the storing of compost was a cause of nutrient depletion as the storage often lacked a roof and/or sealed floor and walls.

Table 1: The table shows the general number of family members, the general farm size, the range of animals on the farms, the most common crops used, the general use of crop residue, and finally the use of each type of compost.

Number of people in the household	2 - 7
Size of the farm [ha]	0.6 - 3.2
Amount of chicken	26 -140
Amount of cows	2 - 4
Amount of buffalos	1 - 5
Amount of pigs	1 - 3
Amount of goats	0 - 9
Amount of ducks	17 - 1000
Commonly used crops	Mango, longan, maize, forage grass and vegetables
Crops used on the farm	Maize and vegetables
Sold crops	Fruits, beans, nuts and sugarcane
Use of forage grass	Feed for cows, buffalos, goats and fishes
Usage of crop residue (Maize, and fruit trees	Left on the field
Usage of crop residue (sugarcane, banana)	Used as fodder
Usage of crop residue (rice, macadamia)	Used in the compost
Usage of chicken manure	Vegetables
Usage of pig, cow, buffalo, and duck manure	Fruit trees

Cows and buffalos are generally stabled under a roof, with a sealed concrete floor. Normally, no walls exist, and feces are collected in a pile next to the concrete floor. There is no roof (or rain cover) on this pile, and it is resting on bare soil. The manure is later moved to a second storage, where it is left to produce compost. This storage is usually under a plastic cover or in sealed plastic bags.

Figure 4:

Cows are generally stabled. The second storage is located behind the cow pen without a roof or sealed floor, and the compost pile is located on the left of the cow pen, covered with a roof. This image belongs to farm nr 8.

Figure 5:

Cows are generally stabled. The second storage is located behind the pen with no roof or sealed floor. The compost pile is not shown in the picture. The home garden is located behind the cow pen. This image belongs to farm nr 4.

For pigs, the pen generally have sealed walls and a floor. The liquid feces are removed from the pen through a small hole in the wall, or through a gutter. Liquids are led to a storage, which is usually a container without a roof, or on a pile on the soil (without a roof). When the feces have dried, they are moved to the second storage, where the composting process start.

Figure 6:

Pigs are generally stabled. The walls and floor are sealed and there is a roof. A hole leads liquids out of the pen. This image belongs to farm nr 8.

Figure 7:

The image shows the second storage of pig waste. There is no roof over the storage. This image belongs to farm nr 8.

Chicken and duck generally graze freely around the house. Manure is collected from the ground around the household and put directly into plastic bags for the composting process. No second storage exists, however as the poultry is not kept indoors, the so-called first storage is exposed to rainfall.

Figure 8: T
he image shows the pen of ducks. There is no sealed floor and no roof or walls. This image belongs to farm number 8.

9.2 Management and N concentrations of the guinea grass strips

In Table 2, the N concentrations of the grass strips, as well as the amount of harvested grass in each field are shown. Clear rows indicate that the grass strips are maintained within the rows whereas the spread rows are cases where the grass has spread and it was no longer possible to differentiate the rows. No rows mean the farmer never planted the grass as contouring grass strips. The SPAD values on the 15 fields varied between 28.2 and 40.1, which represents an estimated N concentration between 0.91 and 1.29 %. The grass was used mainly for cows and buffalos, and in farm 9 to feed the fish in the pond. The harvested amount of grass per day varies from 5 kg to 95 kg. Farm 10 does not use grass at all. A clear pattern of N concentration and the amount of harvested grass per field could not be found.

*Table 2: The measured SPAD values and the corresponding N concentration of the plant in the fields that use grass strips as a means to prevent erosion. The Table also shows the usage of the grass strips, and when they were last fertilized. *Farm 7 had four cows at the beginning of the year, but they were sold, so now they sell the forage grass. YG = Yellow-green, MG = Medium green, DG = Dark green and SR = Spread rows*

Farm ID	**1**		**2**	**3**			**4**	**5**	**6**	**7**	**8**	**9**	**10**		
Field nr	3	6	4	1	2 - 5	6	1	2	1	3	1	1	1	3	4
Mean SPAD value	40.1	36.6	28.2	36.4	33.6	32.7	31.0	38.7	29.4	29.0	31.5	31.7	35.1	31.5	29.7
Std - deviation of the SPAD value	6.1	4.9	3.2	8.2	3.2	4.9	5.8	8.6	2.6	2.9	5.5	4.2	4.8	9.9	5.4
[%] N in plant	1.29	1.18	0.91	1.17	1.08	1.06	1.00	1.25	0.95	0.94	1.02	1.02	1.13	1.02	0.96
Clear Rows?	Yes	Yes	No rows	Yes	Yes	No	No rows	Yes	No	No	Yes	No	No rows	No	No
Usage of fodder grass	Buffalo		Cow	Cow			Cow	Sold	Sold	Cow / no use*	Cow and buffalo	Fish-pond	Not used		
Yield per day (kg)	95 [1]		75	30 - 40			11.3	8.6	1.3	10	60	5	Not used		
Last input	Aug		Aug	Over 1 year ago			Aug	Sept	None	None	May	May	None		

9.3 Nutrient concentrations in composted manure used on the farms

In total, eleven samples were analyzed. The exact values of each analysis can be found in appendix B. The analytical data in table 3 show that chicken manure contained the highest amount of N, duck manure the highest amount of P, and mixed manure the highest amount of K.

*Table 3: Average N, P, and K concentration in composts used on the farms based on different manures. The average chicken compost is based on an average value on the analyzed samples from farms 6,7 and 10 due to similar moisture content. The average value for pig and cow compost is taken from the analyzed samples from farms 7 and 10. With std, it means the standard deviation of the given mean value for each animal compost type. *Contains three analyzed samples and one sample constructed using literature values.*

Type of compost	Nr of samples	Stirring	Composting time	N-content % (std)	P-content % (std)	K-content % (std)	moisture %
Cow manure	1	None	2 month	0.57 (-)	0.37 (-)	0.94 (-)	54.69
Pig manure	1	0 - 1 times at start	2 - 3 month	1.77 (-)	0.78 (-)	0.67 (-)	53.86
Goat manure	1	None	3 weeks	0.97 (-)	0.53 (-)	1.01 (-)	26.85
Chicken manure	4	0 - 1 times at start	0 - 3 month	2.27 (0.87)	1.083 (0.43)	1.113 (0.51)	28.55
Duck manure	1	1 time at start	1 month	0.74 (-)	1.29 (-)	0.87 (-)	38.83
Mixed manure including two components of cow, buffalo, and pig	3*	None or every 15/20 days	2 - 3 months	0.84 (0.62)	0.32 (0.13)	1.77 (0.41)	68.9

9.4 Farm number 1

There are seven fields within the farm and two of the fields is mono-cropped. The farm grows maize, plum, mango, longan, guinea grass, rice, vegetables, and dragon fruit. The fodder grass, 90 % of the vegetables, and all of the maize stay on the farm. All other crops are sold. The farm has chicken, buffalos, and pigs. The animal feed is mainly from the farm. The fields have well-maintained grass rows and the amount of grass harvested per day is the highest out of all the farms with 95 kg per day. The farm has a pond located close to the farmhouse, on a lower elevation, next to the home garden. It is used to irrigate the home garden. The farm has a biogas system. This is the only farm with such a system.

9.4.1 Outline of the farm and nutrient flow

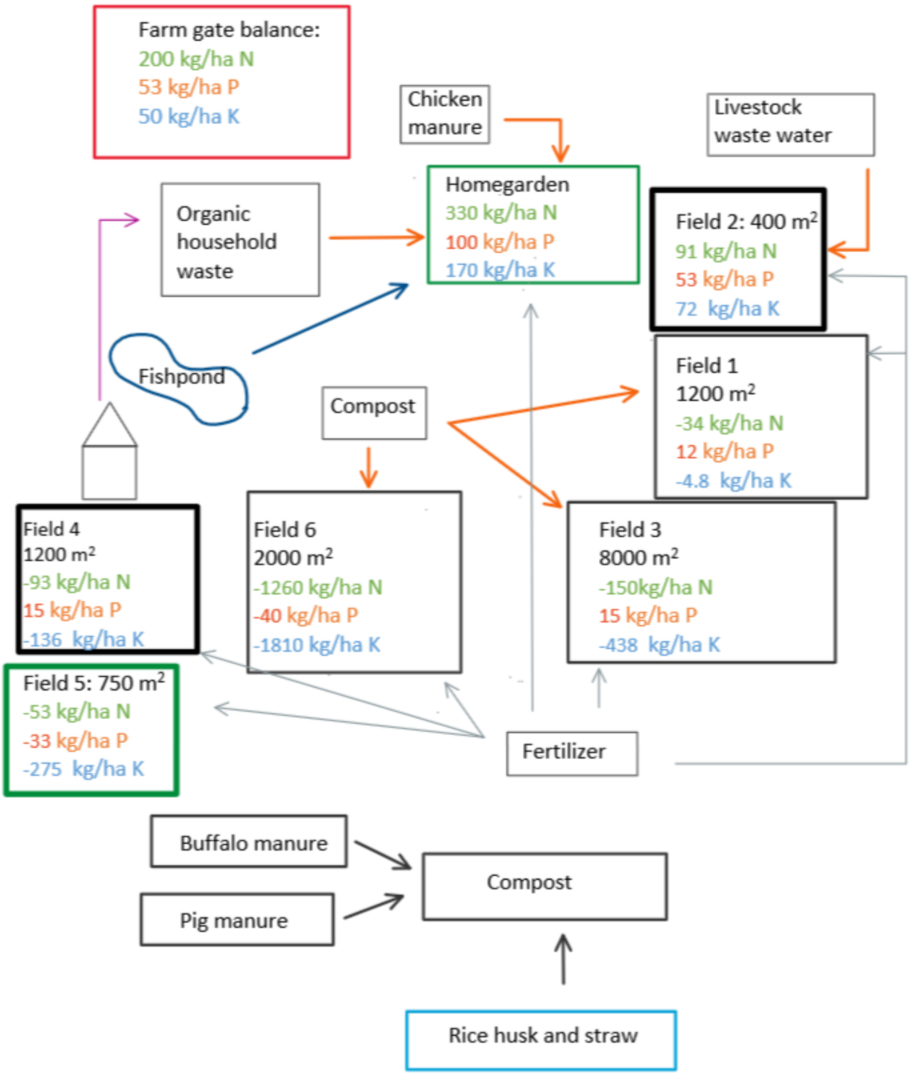

Figure 9: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 1 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows what type of material is used in the compost. This is an extensional part. The ready-to-use compost is used in the figure. Household waste is stored in a separate pile. The pile is either burned or removed by the garbage collector.

9.4.2 Outline of the manure storage

Figure 10 shows the storage and movement of manure for farm 1. The model is the same for all farms. The biogas system, however, is unique for this farm.

The pig pen has a concrete floor, walls, and roof. From the pen, a gutter leads fluids to a biogas system with sealed walls, floor, and roof. Excess feces are led to ”digested livestock waste”, a storage with sealed walls and floor but no roof. The solid material is taken out of the digested livestock waste and put on the soil to dry without a roof. This is later added to the pile

Table 4: Field information for farm number 1

Field number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Type of field	Sloping field	Sloping field	Sloping field	Sloping field	Paddy field	Sloping field	Garden
Area of field m^2	1200	400	8000	1200	750	2000	200
Type of crops/ fruit trees on the field	Maize, plum and mango	Dragon fruit	Plum, longan, mango, maize and guinea grass	Maize (May-Sept) and soybean (Sept-Dec)	Rice	Maize, mango and guinea grass	Vege-tables
Cropping system used	Inter-cropped	Mono-cropped	Inter-cropping	Mono-cropped	Mono-cropped	Inter-cropped	Inter-cropped
Irrigation	No	No	No	No	Yes	No	Yes
Number of plants	20 mango, 10 plum	127 dragon fruit trees	10 longan trees, 64 mango, 72 plum	na	na	130 mango	na
Area of each crop/fruit in m^2	Plum and mango: 180, maize: 1020	Dragonfruit: 400	Grass: 1886, mango, longan, and plum: 1314, maize: 4800	Maize/ Soybean: 1200	Rice: 750	Mango: 500, guinea grass: 800, maize: 680	Vegetables: 200

of buffalo manure.

The buffalo pen has a roof over the majority of the concrete floor. Manure is moved from the pen to a pile outside of the pen on the ground, without a roof, until enough manure is gathered to start the composting process.

When the composting process starts, the manure is covered with plastic. To produce compost, buffalo manure is mixed with rice husks and rice straw according to the following ratio: 10 kg rice husks + 15 kg rice straw + 700 kg fresh manure + 500 g probiotics + 200 g sugar. The mix is covered with plastic and left for 3 months. It is stirred every 20 days. Losses of nutrients occur during manure management due to the lack of a roof and through storing the compost without sealed ground.

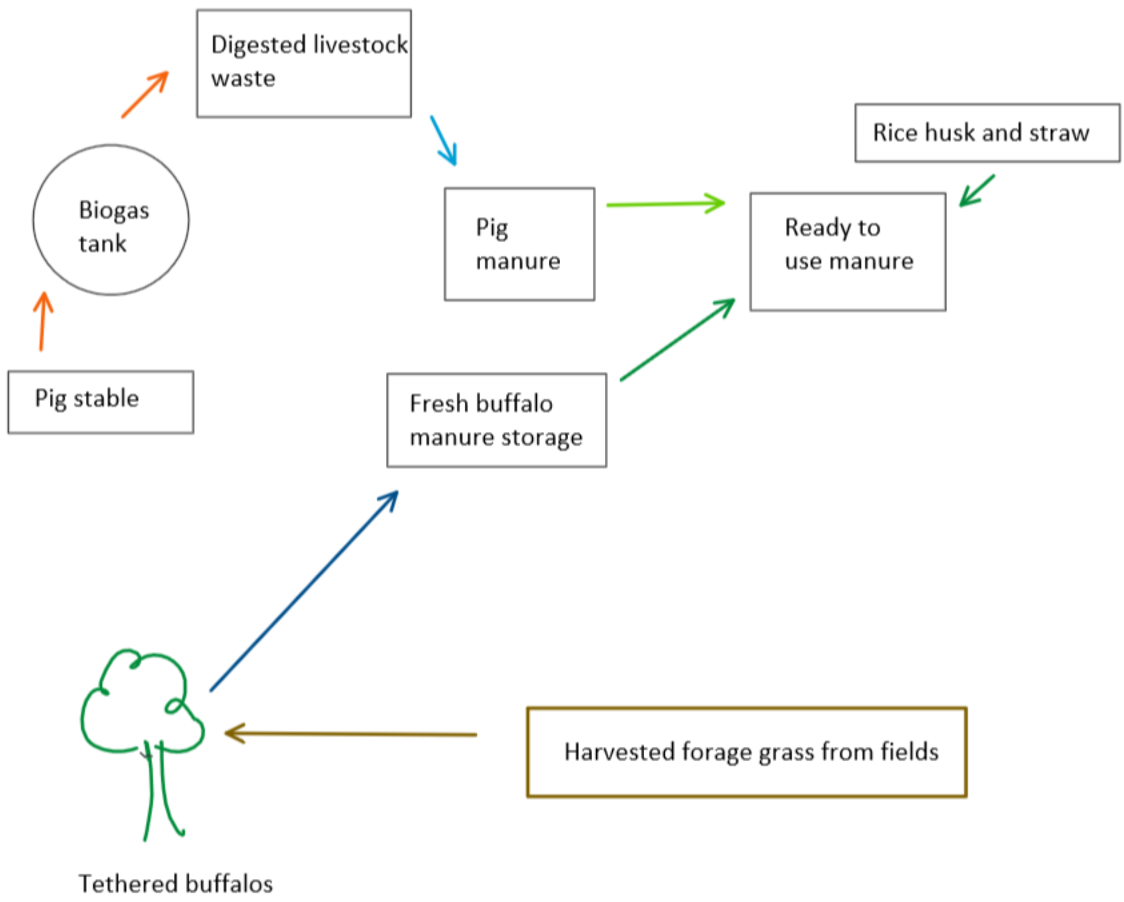

Figure 10: Manure relocation and storage at farm 1. The picture shows the manure storage for farm 1 but will be used as a model for all the farms. Harvested forage grass represents the source of fodder used to feed the animals

9.5 Farm number 2

The farm has five fields, out of which two are mono-cropped fields. Specific for this farm is that it grows elephant grass as a sole crop. The elephant grass is grown on a sloping field in a vertical direction. On the side of this field is one field with macadamia and maize Inter - cropped and on the other side is a field with sole-cropped sugarcane. The grass does not have an apparent effect on erosion as it is not grown as contour grass strips. This could be seen, as surface water had previously created a vertical deep furrow in the soil. The N, and K uptake from the grass field is very high, as can be seen in the nutrient balances on field 4 in figure 11. This farm grows macadamia, maize, sugarcane, mango, longan, vegetables, and fodder grass. Fodder grass, vegetables, maize, and the crop residue from maize and sugarcane stay on the farm. All other crops are sold. The farm has cows, pigs, and chicken. The animal feed is mainly from the farm. 75 kg of grass is harvested per day.

9.5.1 Outline of the farm and nutrient flow

Table 5: Field information for field number 2

Field number	**1**	**2**	**3**	**4**	**5**
Type of field	home garden	Sloping field	Sloping field	Sloping field	Sloping field
Area of field m^2	1200	2000	6000	500	22000
Type of crops/ fruit trees on the field	Mango, longan, Vegetables	Macadamia	Macadamia, maize	Elephant grass	Sugarcane
Cropping system used	Inter-cropped	Mono-cropped	Inter-cropped	Mono-cropped	Mono-cropped
Irrigation	Yes	No	No	No	No
Number of trees and/or seeds	100 mango trees, 15 longan	50 macadamia trees (four-month-old)	200 macadamia trees (seven years old), 6 kg maize seeds	na	na
Area of each crop/ fruit in m^2	Mango: 600, longan: 90 and vegetables: 500	Macadamia: 2000	Maize: 2900 and macadamia: 1500	500	22 000

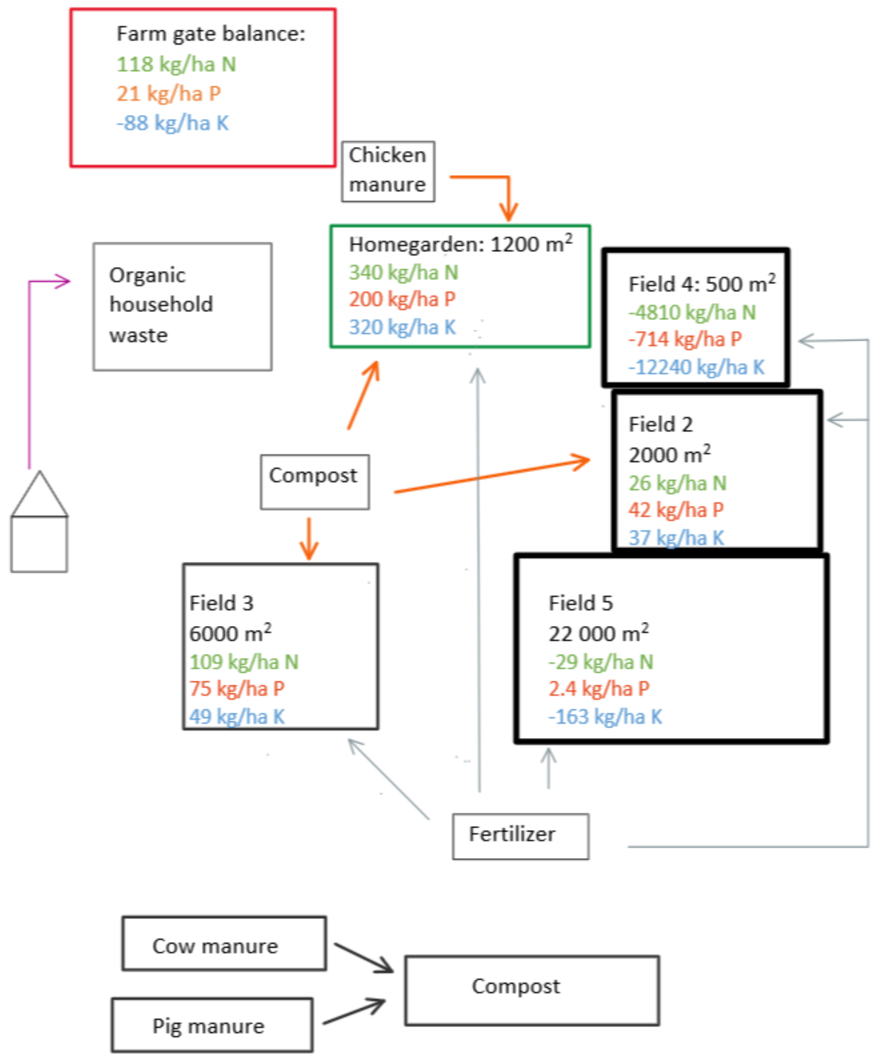

Figure 11: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 2 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows what type of material is used in the compost. This is an extensional part. The ready-to-use compost is used in the figure. Household waste is stored in a separate pile. The pile is either burned or removed by the garbage collector.

9.5.2 Outline of the manure storage

The cow pen has no walls but a concrete floor and roof. The pig pen has a concrete floor, walls, and roof. From the cow pen, fluids are lost due to the lack of walls. Fresh pig and cow manure are first stored outside of the pen, on the soil without a roof. It is later moved to a second storage (on soil without a roof) where its placed to dry. After 3 months, with stirring once per month; it is ready to use. It is then put in nylon bags that are placed under the fruit trees until it is time to fertilize the trees.

9.6 Farm number 3

This farm has six fields with similar agroforestry (AF) system. The farm grows fruit and nut trees, grass rows, maize, vegetables, and black beans. Vegetables, fodder grass, and part of the maize stay on the farm. Some maize, black beans, and all fruit are sold. Except for black beans, which are not fertilized, all the crops are given the same type of fertilizer. The farm has cows, pigs, and chicken. The most animal feed comes from the farm. 35 kg of grass is harvested per day. In fields one to five the rows are clear. In field six the grass has spread.

9.6.1 Outline of the farm and nutrient flow

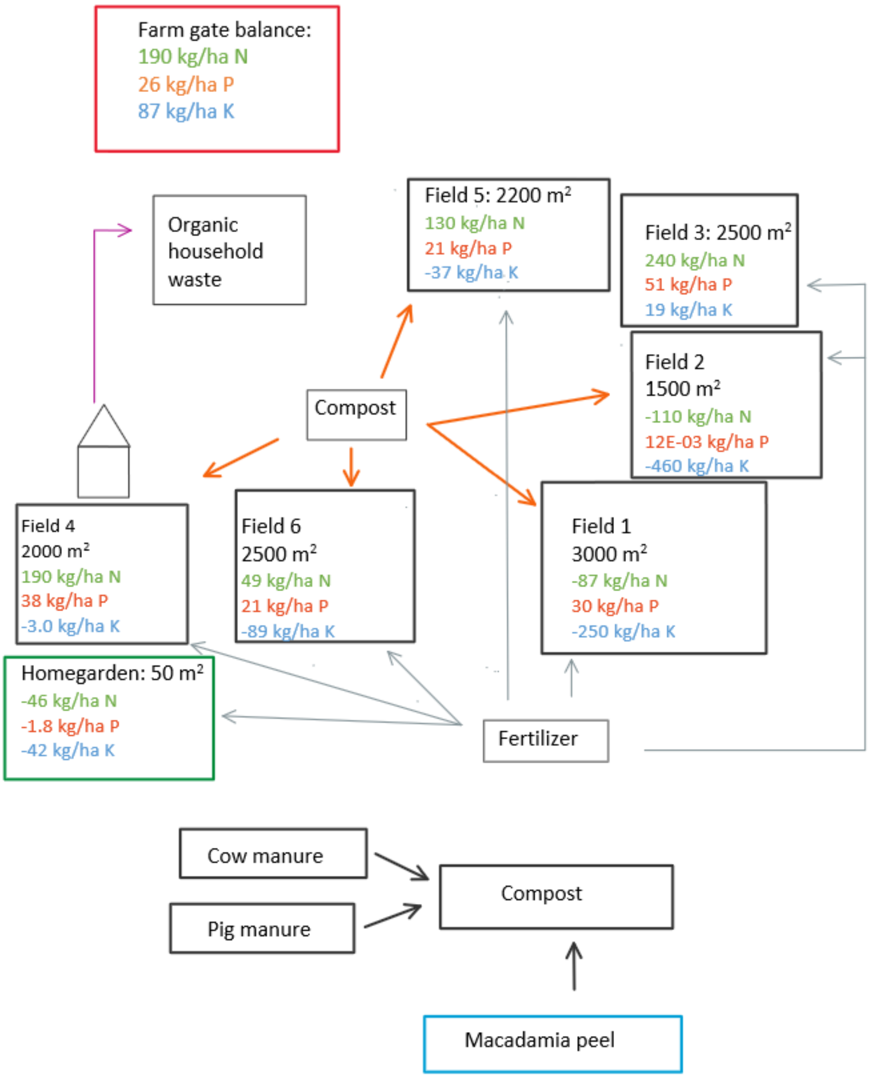

Figure 12: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 3 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows what type of material is used in the compost. This is an extensional part. The ready-to-use compost is used in the figure. Household waste is stored in a separate pile. The pile is either burned or removed by the garbage collector.

Table 6: field information to farm 3

Field number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Type of field	Sloping field	Sloping field	Sloping field	Sloping field	Sloping field	Sloping field	Home-garden
Area of field m^2	3000	1500	2500	2000	2200	2500	50
Type of crops/ fruit trees on the field	Macadamia (10 years old), guinea grass and elephant grass and black beans	Longan, guinea grass and elephant grass	Mango, maize, and guinea grass	Longan, maize and guinea grass	Plum, maize, and Guniea grass	Macadamia (1-year-old), maize and guinea grass	Vegetables
Cropping system used	Inter-cropped	Inter-cropped	Inter-cropped	Inter-cropped	Inter-cropped	Inter-cropped	Mono - cropped
Irrigation	No	No	No	No	No	No	Yes
Number of trees and/or seeds	106 macadamia, 5 kg black bean seeds	40 longan	120 mango	74 longan	50 plum trees	150 macadamia	na
Area of each crop/ fruit tree in m^2	Black beans: 400, macadamia: 1590 and grass: 1010	Longan: 600 and grass: 900	Mango: 1800, grass: 340, maize: 360	Longan: 1110, grass: 270, maize: 620	Plum: 750, grass:300 and maize 1150	Macadamia: 1800, grass:340 and maize: 360	Vegetables: 50

9.6.2 Outline of the manure storage

The cow pen has a concrete floor and roof but no walls. The pig pen has a concrete floor, roof, and walls. From the cow pen, fluids are lost due to the lack of walls. No gutter is leading the fluids from the pig pen to the storage, so these fluids are also lost. Pig manure is stored together with cow manure on a concrete floor with brick walls. The compost is covered with plastic. 1000 kg fresh manure (pig + cow) is mixed with 500 kg macadamia peel + 2 bags of probiotica + 1 kg sugar per time. The mix is covered with plastic and turned over every 15:th day. After 2 months the compost is ready to use.

9.7 Farm number 4

This farm has four fields, two of them being Mono-cropped. It is mainly grown in sugarcane and maize, but also longan, mango, fodder grass, pomelo, and vegetables. 20 - 30 kg/ day of sugarcane crop residue, fodder grass, longan (this year), maize, and vegetables stay on the farm, the rest is sold. The farm has cows, ducks, and chicken. The animal feed is mainly from the farm. 11.3 kg of grass is harvested per day. Rows on the contours are not visible.

9.7.1 Outline of the farm and nutrient flow

Table 7: Field information for farm 4

Field number	**1**	**2**	**3**	**4**
Type of field	Sloping field	Sloping field	Sloping field	home garden
Area of field m^2	1700	3000	2500	1000
Type of crops/ fruit trees on the field	Sugarcane, guinea grass, longan and mango	Sugarcane	Maize	Mango, longan, pomelo and vegetables
Cropping system used	Inter-cropped	Mono-cropped	Mono-cropped	Inter - cropped
Irrigation	No	No	No	Yes
Number of trees and/or seeds	5 longan, 5 mango	-	5 kg seeds	20 mango, 4 longan, 10 pomelo
Area of each crop/fruit tree in m^2	Sugarcane: 1500, guinea grass: 45, mango and longan:90	Sugarcane: 3000	Maize: 2500	Vegetables: 100, mango, longan and pomelo: 900

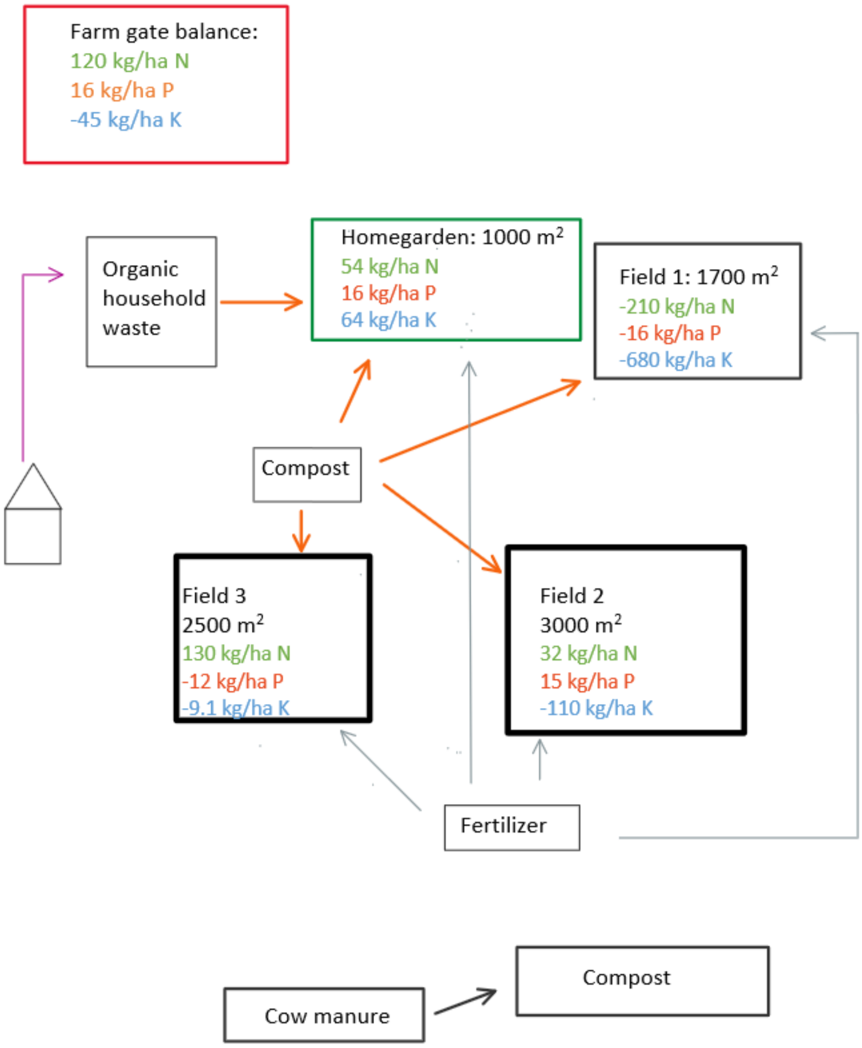

Figure 13: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 4 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows what type of material is used in the compost. This is an extensional part. The ready-to-use compost is used in the figure. Household waste is stored in a separate pile and not used. The blue arrows from the fishpond indicate that nutrient-rich water is used to water the fields.

9.7.2 Outline of the manure storage

The cow pen has a sealed roof, no walls, and a concrete floor. The manure is removed from the pen every day and put in a pile behind the pen, without a roof, until it´s dry. When it´s dry it is put in plastic bags and left under the fruit trees. After two months the compost is ready to use. Behind the pen is the home garden, so losses from the cow pen end up in the home garden. Some vegetables are grown directly adjacent to the cow pen.

9.8 Farm number 5

The farm has four fields, out of which two are mono-cropped. The farmer grows sugarcane, banana, guinea grass, mango, longan, pomelo, and vegetables. Vegetables, maize, bananas, and banana trunk, 30 % of the pomelo, and part of the grass stay on the farm. Mango, longan, sugarcane, 70 % of the pomelo, and most of the fodder grass are sold. The farm has goats and chicken. The main feed is from the farm. 8.6 kg of grass is harvested per day and rows have spread but it is still easy to see where they originally were planted.

9.8.1 Outline of the farm and nutrient flow

Table 8: Field information to farm 5

Field number	**1**	**2**	**3**	**4**
Type of field	home garden	Sloping field	Sloping field	Sloping field
Area of field (m^2)	450	5000	12800	200
Type of crops/ fruit trees on the field	Pomelo, mango, longan and vegetables	Mango, longan, maize and guinea grass	Sugarcane	Banana
Cropping system used	Inter - cropped	Inter - cropped	Mono-cropped	Mono-cropped
Irrigation	Yes	No	No	No
Number of trees and/or seeds	15 pomelo, 25 mango, 20 longan	4 kg maize seeds, 84 mango, 70 longan	na	550 trees
Area of each crop/fruit tree in m^2	Pomelo: 100, mango:150, longan: 150, vegetables: 50	Maize: 1800, mango: 500, longan: 530 and guinea grass: 2200	Sugarcane: 12800	Banana: 200

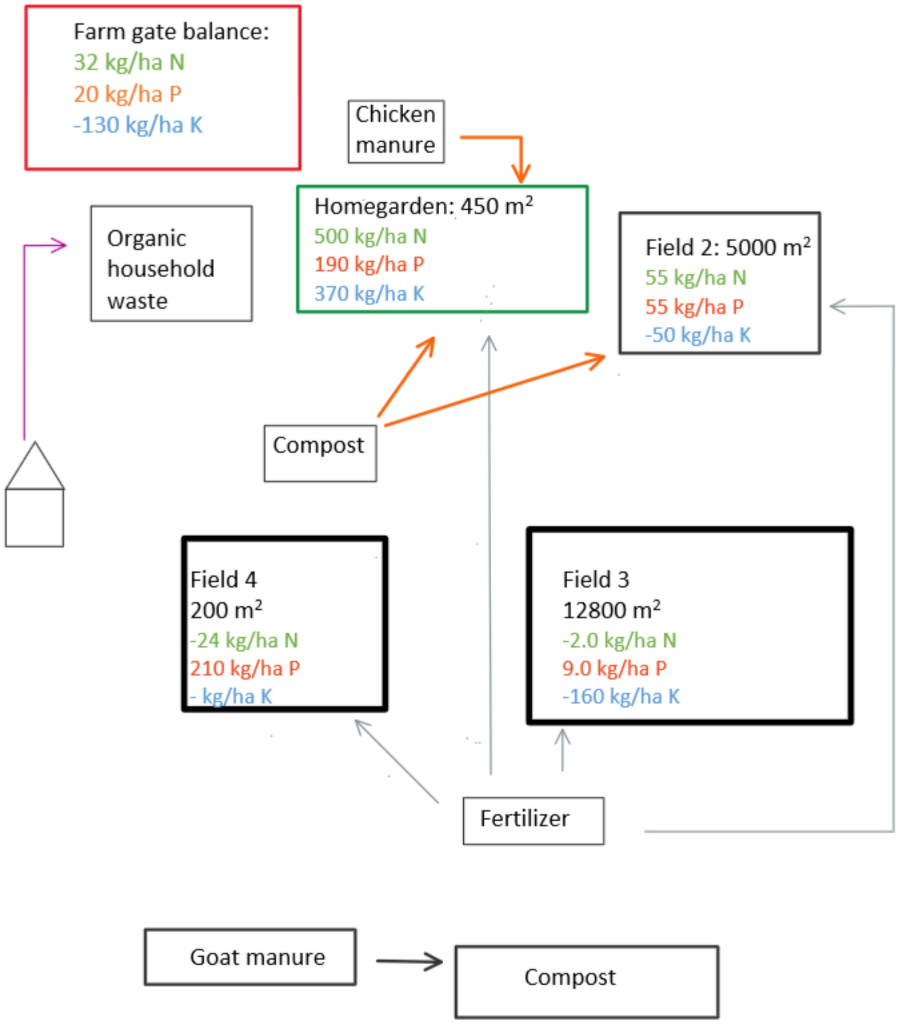

Figure 14: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 5 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows what type of material is used in the compost. This is an extensional part. The ready-to-use compost is used in the figure. Household waste is stored in a separate pile. The pile is either burned or removed by the garbage collector.

9.8.2 Outline of the manure storage

Goats are kept in a wooden barn. They occasionally graze on the fields. Goat manure is collected under the barn (placed on a hill). The manure is collected from soil ground with a roof, but exposed to rain from the sides and from runoff rainwater. The second storage is in nylon bags placed under the fruit trees. Chicken manure and goat manure are stored in separate bags. The manure is left in the bag for two weeks until the compost is ready to be used.

9.9 Farm number 6

There are six fields on the farm. Three fields are mono-cropped. Sugarcane, dragonfruit, maize, longan, mango, guinea grass, and vegetables are grown on the farm. Vegetables and maize stay on the farm. Everything else, including crop residue, is sold. 1.3 kg of grass is harvested each day. The rows are not clear. The home garden has a very high accumulation of N, P, and K. Bought fertilizers are used for the vegetables in the home garden, which is not usually the case. The farm has pigs and chicken. The animal feed is mainly from the farm.

9.9.1 Outline of the farm and nutrient and nutrient flow

Table 9: Field information for farm 6

Field number	**1**	**2**	**3**	**4**	**5**	**6**
Type of field	Sloping field	Sloping field	Sloping field	Sloping field	Sloping field	home garden
Area of field m^2	2000	3200	4300	1500	1000	200
Type of crops/ fruit trees on the field	Mango, longan, guinea grass	Mango, longan, maize	Sugarcane	Dragonfruit	Maize	Mango, longan, vegetables
Cropping system used	Inter - cropped	Inter - cropped	Mono-cropping	Mono-cropped	Mono-cropped	Inter - cropped
Irrigation	No	No	No	No	No	No
Number of trees and/or seeds	45 mango, 30 longan	100 mango, 100 longan, 3.8 kg maize		222 trees	2 kg seeds	-
Area of each crop/fruit tree in m^2	Mango: 540, longan: 360, guinea grass: 160	Mango: 800, longan: 800, maize: 1600	Sugarcane: 4300	Banana: 1500	Maize: 1000	Longan: 50, mango: 60, vegetables: 90

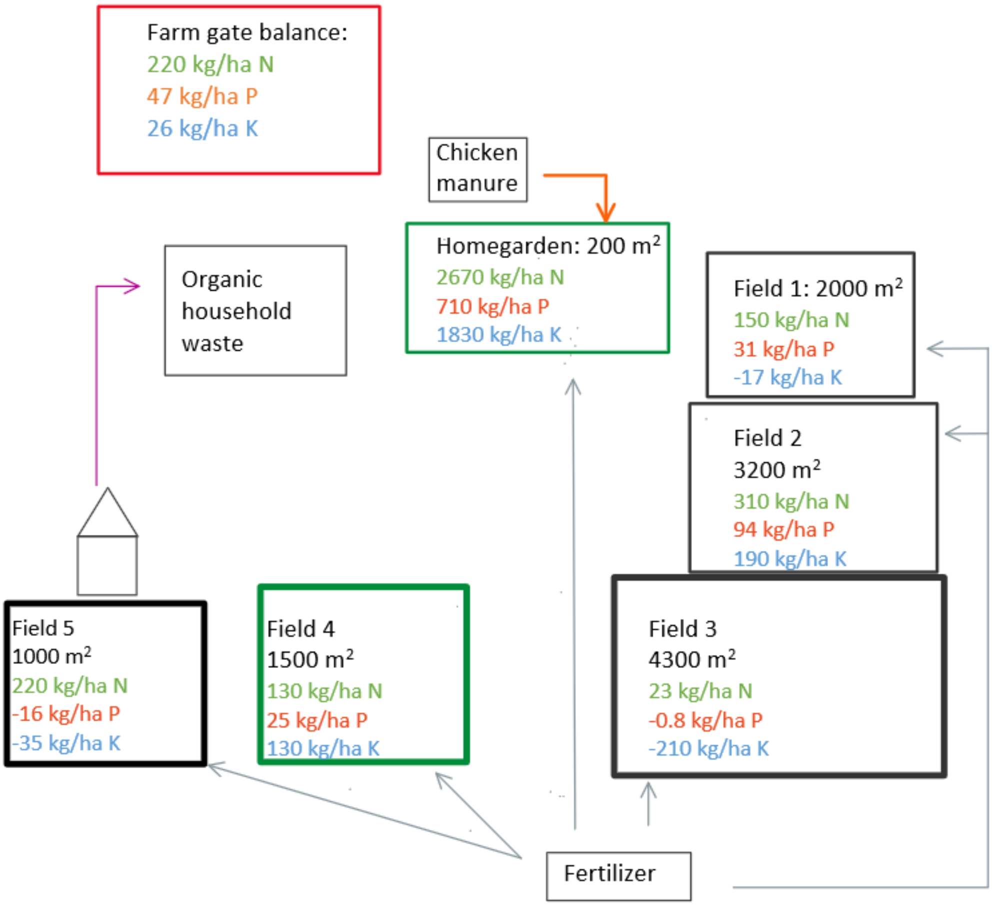

Figure 15: The figure shows the nutrient balance of nitrogen, phosphorus and potassium on each field at farm 6 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frames mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows which type of material is used in the compost.

9.9.2 Outline of the manure storage

Pig manure from the two pigs is not collected. Pen is rinsed clean with water. Through rinsing the pig stable with water, nutrients are lost from the farm. The loss of N was calculated to be 17 kg/year, the P loss 4.9 kg/ year, and the K loss 12 kg/ year.

9.10 Farm number 7

The farm has five fields, none of them mono-cropped. The farm grows maize, forest trees, longan, mango, pomelo, plum, lemon, and guinea grass. Vegetables, lemon, pear, pomelo, and maize are used on the farm. All other crops are sold. Ten kg of grass is harvested each day and the rows are spread. Most of the grass is being cut with a trimmer and left on the field. The farm has cows, pigs, and chicken. The animal feed is mainly from the farm. The farm has a pond, located on a lower elevation, beneath the house and stables. Nutrient losses from especially the manure storage are likely to end up in the pond. The pond contains fish, which are given fodder grass as feed. The dragonfruit fields and home garden are irrigated with water from the pond.

9.10.1 Outline of the farm and nutrient flow

Table 10: Field information of farm 7

Field number	**1**	**2**	**3**	**4**	**5**
Type of field	Flat field	Flat field	Sloping field	Sloping field	home garden
Area of field m^2	3700	1200	8000	1300	100
Type of crops/ fruit trees on the field	Dragonfruit, mango	Dragonfruit, pear	Longan, mango, pomelo, plum, lemon, guinea grass	Maize, forest tree	Vegetables
Cropping system used	Inter - cropped	Inter - cropped	Inter - cropped	Inter - cropped	Inter - cropped
Irrigation	Yes	No	No	No	Yes
Number of trees and/or seeds	50 mangos, 200 dragonfruit	30 pear, 40 dragonfruit	100 longan, 400 mango, 25 pomelo, 10 plum, 6 lemon trees	2.7 kg maize seeds	-
Area of each crop/fruit tree in m^2	Dragonfruit: 3200, mango: 450	Dragonfruit: 640, pear:480	Guinea grass: 1000, fruit trees: 5700	Maize: 1300, forest trees: -	-

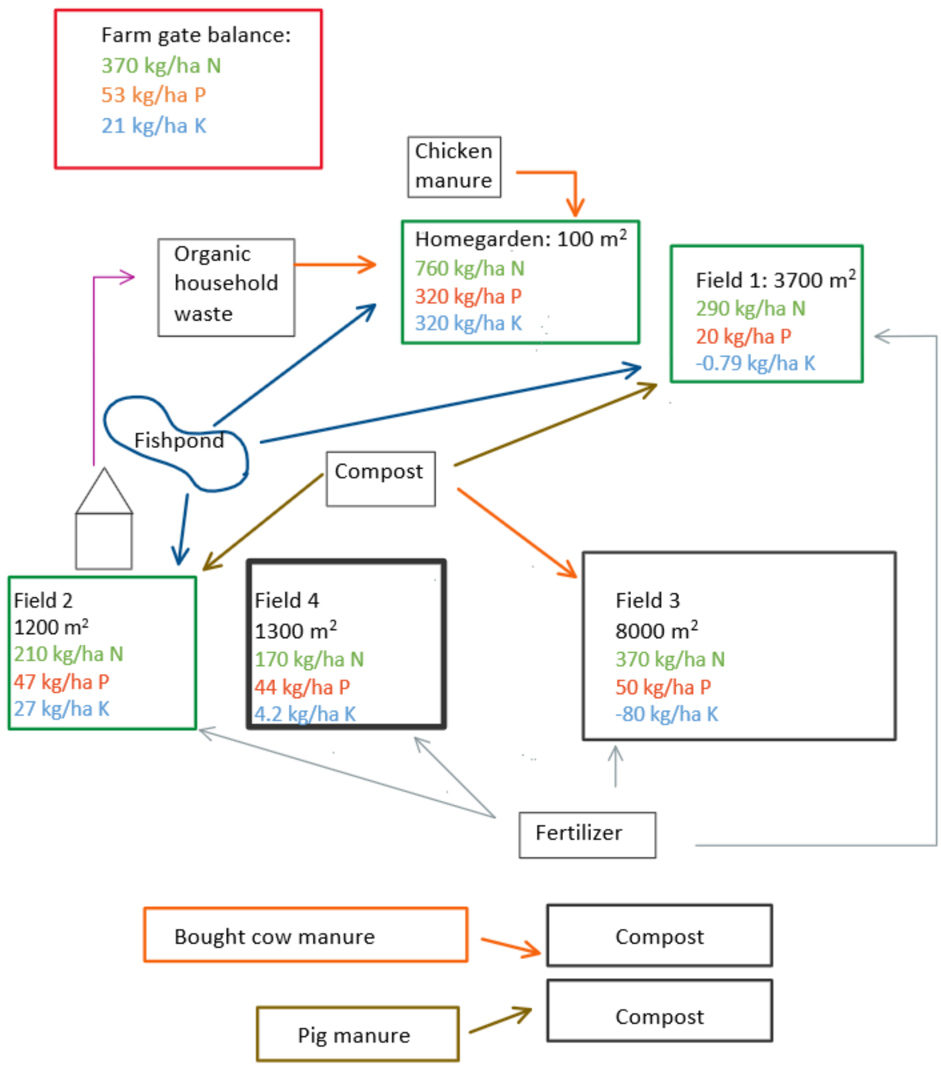

Figure 16: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 7 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows which type of material is used in the compost

9.10.2 Outline of the manure storage

The walls and floor of the pig pen are made of concrete. Pig manure is collected from the barn and stored in a hole in the ground, consisting of brick walls and a plastic roof. Probiotics are added and the manure is stirred one time before leaving it for two months. Chicken manure and pig manure are stored in separate holes in the ground. When the compost is ready to use it is mixed together before being added to the field. Cow compost is bought.

9.11 Farm number 8

The farm has four fields. Three of them are mono-cropped. Vegetables, maize, sugarcane, mango, longan, and guinea grass are grown. 200 kg of vegetables per year, guinea grass, 1.8 tons of maize and sugar cane residue stay on the farm. The rest is sold. This farm has buffalos, cows, pigs, ducks, and chicken. The animal feed is mainly from the farm. 60 kg of fodder grass is cut each day and the rows are kept clear and structured.

9.11.1 Outline of the farm and nutrient flow

Table 11: Field information for farm 8

Field number	**1**	**2**	**3**	**4**
Type of field	Sloping field	Sloping field	Sloping field	home garden
Area of field m^2	8000	1500	2000	600
Type of crops/ fruit trees on the field	Mango: 2250, longan: 2250 plum: 300, maize and guinea grass	Sugarcane	Maize	Vegetables
Cropping system used	Inter - cropped	sole-cropped	sole-cropped	Inter - cropped
Irrigation	No	Yes	Yes	Yes
Number of trees and/or seeds	150 mango, 150 longans, 20 plum and 5.5 kg maize seeds		4 kg maize seeds	
Area of each crop/fruit tree in m^2	Maize: 2700, longan: 2250, mango: 2250 guinea grass: 315	Sugarcane: 1500	Maize: 2000	Vegetables: 600

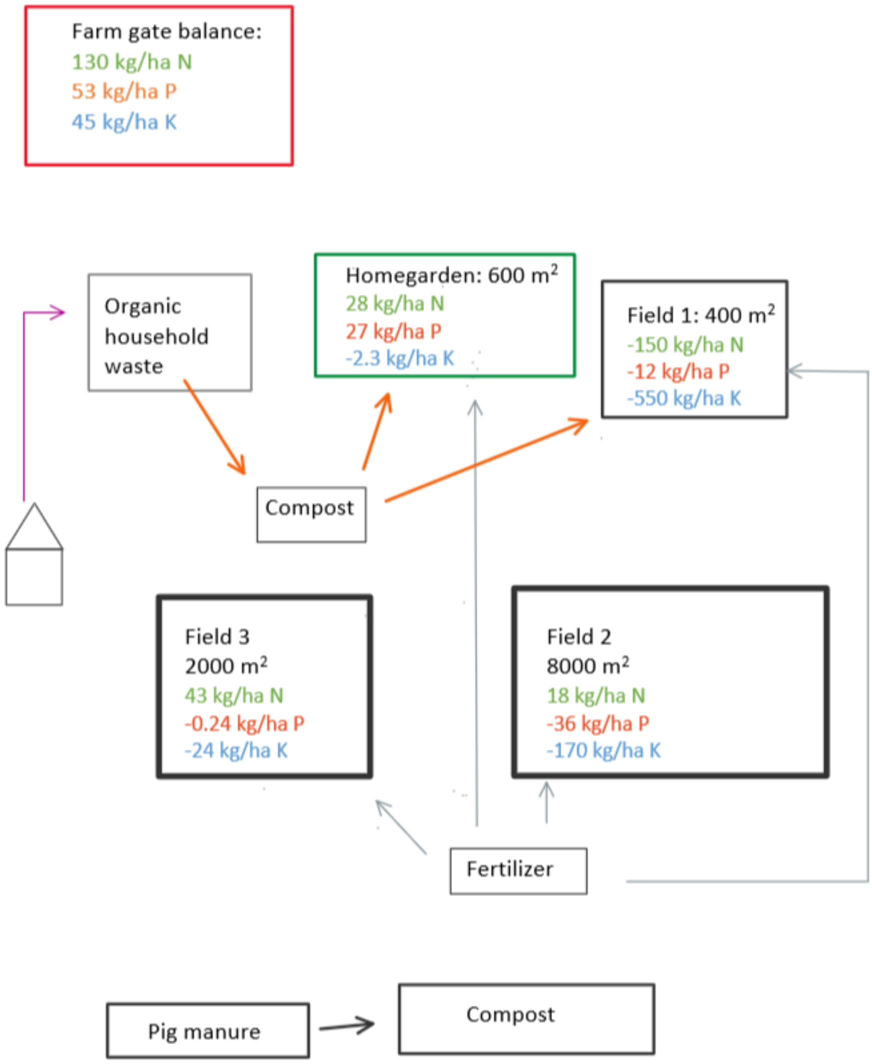

Figure 17: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 8 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows which type of material is used in the compost

9.11.2 Outline of the manure storage

Cows and buffalos are tethered on a concrete floor and under a roof (no walls). Pigs are in a pen with a concrete roof and walls and under a roof. Manure is taken from the concrete floor of the cow- and pig pen and stored in two separate piles. These piles lack roofs and sealed floors. Fluids from the pig pen are led directly to the pile of pig feces. From these piles, the manure is moved to a second storage with a concrete floor, brick walls, and a roof. Manure from buffalo and cow is mixed. Pig manure is stored separately. Two bags of probiotics are added to two tons of manure. The manure is stored for two months before use. No stirring is applied.

9.12 Farm number 9

The farm has four fields. One is mono-cropped. Vegetables, macadamia, maize, mango, longan, and guinea grass are grown. Vegetables and fodder grass stay on the farm. The rest is sold. Due to small trees and that some of the crops were yet to be harvested, the field balance at this farm is affected by a high nutrient input and low nutrient output. 3000 ducks and 20 000 kg of duck compost are sold each year, and the farm is seemingly characterized by a high phosphorus depletion. The farm also has chicken. The main source of animal feed is bought fodder. A pond with fish is located on the farm. It is used to irrigate the home garden. The house and home garden are located on a higher elevation than the pond, so nutrients from the home garden are likely to end up in the pond. Five kg of grass is cut each day, and the rows no longer follow the contour lines. This farm does not have a septic tank, but waste from the privy is buried far from the house and the fields.

9.12.1 Outline of the farm and nutrient flow

Table 12: Field information on farm 9

Field number	**1**	**2**	**3**	**4**
Type of field	Sloping field	Sloping field	home garden	Sloping field
Area of field m^2	1300	4000	20	500
Type of crops/ fruit trees on the field	Mango, longan, guinea grass	Macadamia (3 month old)	Vegetables	Macadamia, maize
Cropping system used	Inter - cropped	Inter - cropped and sole-cropped	Inter - cropped	Inter - cropped
Irrigation	No	No	Yes	Yes
Number of trees and/or seeds	50 mango, 50 longan	100 macadamia	-	0.5 kg seeds
Area of each crop/fruit tree in m^2	Guinea grass: 400, mango: 450, longan: 450	Macadamia: 4000	Vegetables: 20	Maize: 490, macadamia: 10

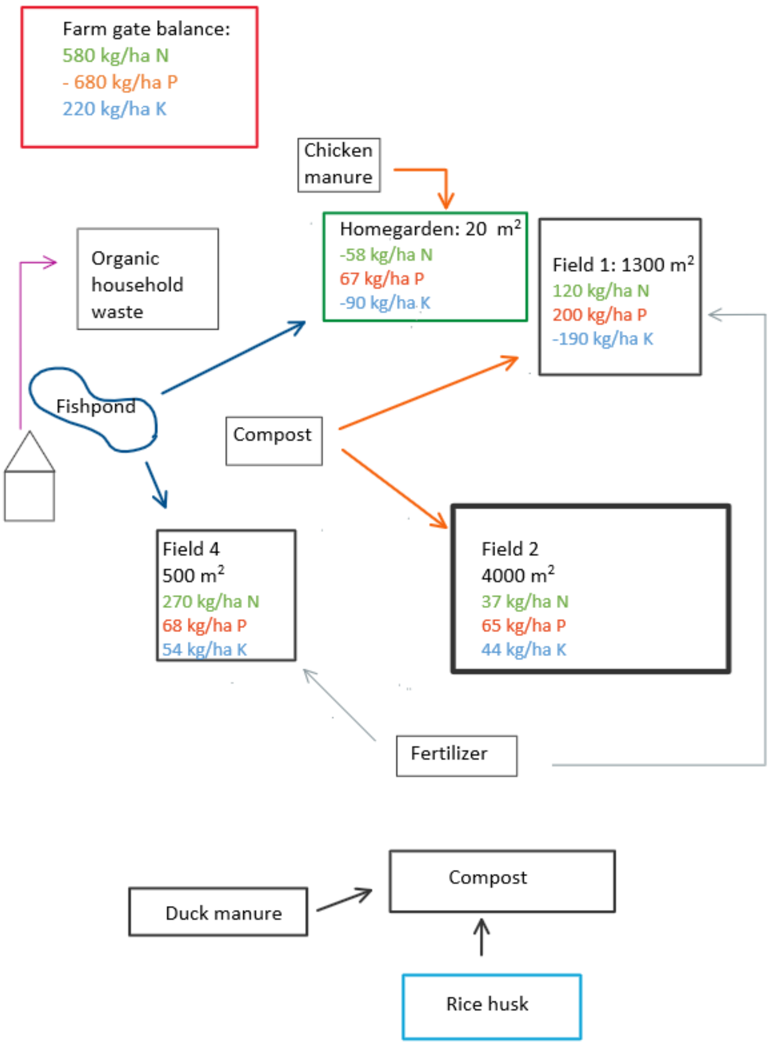

Figure 18: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 9 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows which type of material is used in the compost

9.12.2 Outline of the manure storage

Manure is collected in the pen. The pen does not have a sealed floor and a partially covered plastic roof. Two tons of fresh duck manure is mixed with 200 kg of rice husk. The mix is stirred and put in bags for one month. Fourteen tons are used on the farm per year and 10 tons of compost is sold each year.

9.13 Farm number 10

The farm has seven fields. Three of them are mono-cropped. The farm grows coffee trees, mango, longan, rice, maize, sugarcane, guinea grass, and vegetables. Vegetables, maize, and rice are used on the farm. All other crops are sold. The grass is not harvested and has spread. The farm has pigs and chicken. The animal feed is mainly from the farm. This farm has no septic tank, and waste from the privy is buried next to the pig stable, which is located next to the coffee tree plantation.

9.13.1 Outline of the farm and nutrient flow

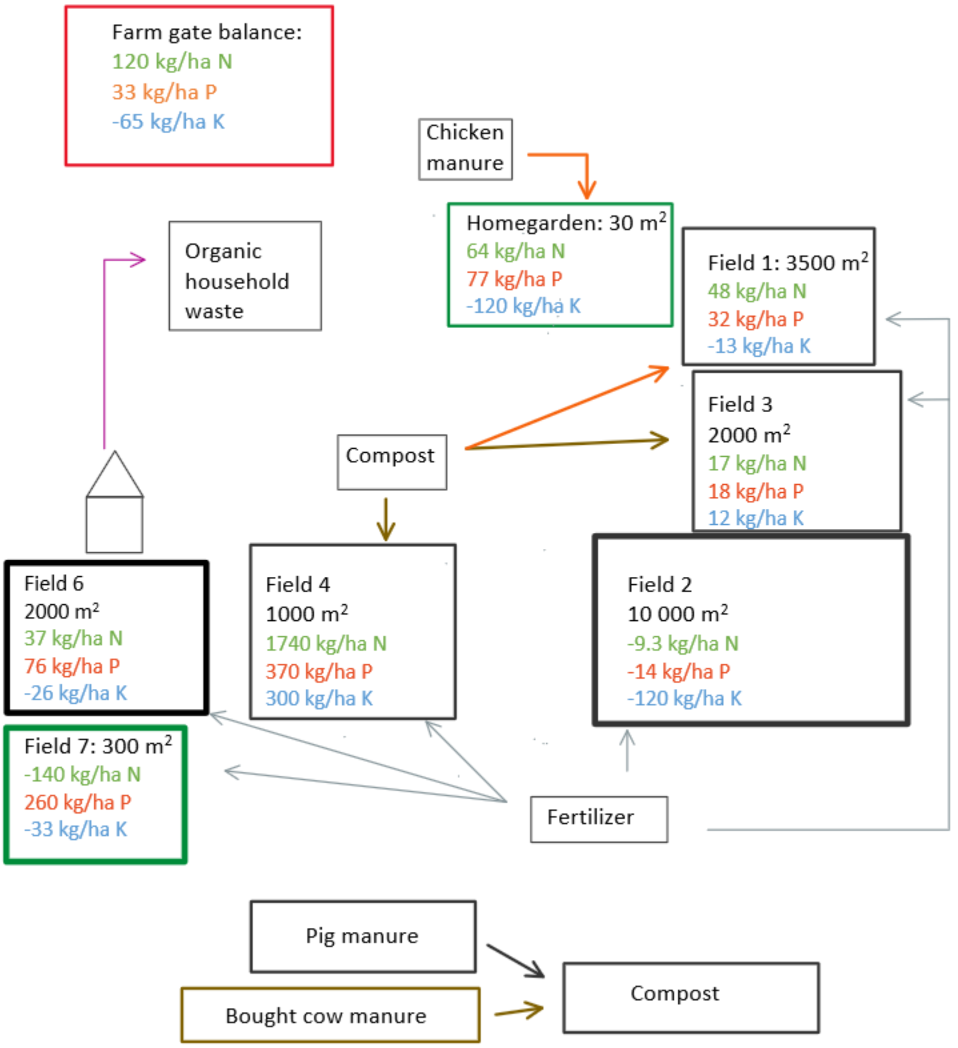

Figure 19: The figure shows the nutrient balance of nitrogen, phosphorus, and potassium on each field at farm 10 as well as the farm gate balance on the entire farm. The arrows show how the different components move within the farm. Green field lines represent flat fields while black fields are uphill fields. Bold lines frame mono-cropped fields without agroforestry practice. The figure is not according to scale. The figure also shows which type of material is used in the compost

9.13.2 Outline of the manure storage

The property has two pig pens with a privy placed in the middle. The privy does not have a septic tank, and the waste is buried next to the privy. The pig pens have sealed concrete floors with wooden roofs, but no sealed walls. First fresh storage is located behind the pens. No floor or walls exist, and only one of the piles has a roof. Storage is in direct connection with field 1, so lost fluids are flushed into field 1. After first storage (when dried) the manure is placed in nylon bags where it is further decomposed for 2-3 months without adding anything or stirring it.

Table 13: Field information for farm 10

Field number	**1**	**2**	**3**	**4**	**5**	**6**	**7**
Type of field	Sloping field	Sloping field	Sloping field	Sloping field	home garden	Sloping field	Paddy field
Area of field m^2	3500	10 000	2000	1000	30	2000	300
Type of crops/ fruit trees on the field	Mango, longan, coffee, guinea grass	Sugarcane	Mango, guinea grass	Longan, guinea grass	Vegetables	Maize	Rice
Cropping system used	Inter - cropped	Mono-cropped	Inter - cropped	Inter - cropped	Inter - cropped	sole-cropped	sole-cropped
Irrigation	Yes	No	No	No	Yes	No	No
Number of trees and/or seeds	10 mango, 10 longan, 300 coffee		30 mango	20 longan		5 kg seeds	6 kg seeds
Area of each crop/fruit tree in m^2	Longan: 360, mango: 120, Coffee: 1500, Grass: 1000	Sugarcane: 10000	Mango: 450, grass: 150	Longan: 300, Grass 100	Vegetables: 30	Maize: 2000	-

9.14 Farm-gate balances

The highest calculated accumulation and depletion of nutrients was found on farm 9 (Table 14). Generally, the N balance was positive on all farms. The average accumulation on the farm level was between 30 and 580 kg/ha. N depletion does still occur on field level as can be seen under section 9.1.

For P, the trend is generally that the farms had positive values. The values ranged from -680 to 53 kg/ha. The low value sticks out as an outlier and occurred on farm number 9, which sells 3000 ducks and 10 000 kg of duck manure annually, and also buys most of the feed. The large nutrient export contributes to the low value of P. Selling animals and manure are not general traits for the farms in the study. The highest accumulation of P can be seen on farms 1, 7, and 8 with 53 kg/ha P. When looking at the field level, as mentioned for N, it varies, and there is a high frequency of P-depletion on the fields.

The calculated K balances vary between -130 and 220 kg/ha on the farms. K depletion occurs on farm 2, 4, 5, and 10, with the highest depletion on farm 5. Farm 5 is characterized by a large field of sugarcane, and the other farms with high K depletion have many or large fields of fodder grass. The highest accumulation occurs on farm 9 with 220 kg/ha K.

Table 14: The Table shows the calculated nutrient values from the farm gate balance for each farm. Values are given in kg/ha. The red values show accumulation and the blue values nutrient depletion. Bold values represent the highest accumulation or depletion. No N depletion occurs.

Farm ID	N [kg/ha]	P [kg/ha]	K [kg/ha]
1	200	**53**	50
2	120	21	-88
3	190	26	87
4	120	16	-45
5	32	20	**-130**
6	220	47	26
7	370	**53**	21
8	130	**53**	45
9	**580**	**-680**	**220**
10	120	33	-65

9.15 Field nutrient balance for different crops

In Table 15 it can be seen that dragonfruit fields overall had positive nutrient balances, indicating accumulation of nutrients. Except for a small nutrient depletion of P, no nutrient depletion occurs.

For AF systems with maize and grass, Table 15 shows that the fields have a P balance close to zero, while K seems to be depleted from the fields. When looking at every field individually, field number 6 at farm 1 stands out with a low value of -1810 kg/ha K and -1260 kg/ha N. When removing this field, the mean values changed to + 52 kg/ha N, 2 kg/ha P and -160 kg/ha K, which shows that this field does not belong to the normal values. The trend that can be seen is a P balance close to zero or a loss of P in these systems.

For fields with AF systems including maize but no grass, the trend is that N has accumulated on the fields, while P and K have values close to zero. Accumulation or depletion does not seem to occur to a great extent

For grass as the only herbaceous component, Table 15 shows that there is an N accumulation, as well as a lesser P accumulation and a K depletion. However when looking at the range of values, the accumulation of 1740 kg/ha N seems to be an outlier. When removing this field (field nr 4 on farm 10), the values are 38 kg/ha N, 43 kg/ha P, and - 210 kg/ha K. For the sugarcane, a clear trend of K depletion can be seen in Table 15.

Table 15: The Table shows the mean values and range of values for some cropping systems. Values are given in kg/ha. AF=Agroforestry system. The values in the brackets show the values when outliers have been removed.

System	**N [kg/ha]**		**P [kg/ha]**		**K [kg/ha]**		n
	Mean	**Range**	**Mean**	**Range**	**Mean**	**Range**	
AF w maize and grass	-110 (52)	(-150) -1260 - +190 (+240)	19 (27)	(-12) -40 - (+55) +187	(-160)-370	(-550) - 1810 - + 19	8
AF w maize	160	-34 - +310	64	+ 12 - + 94	71	-4.8 - + 190	4
Sole maize	120	37 - +220	18	-16 - + 76	-14	-35 - + 9.1	5
Fruit tree w grass	230 (38)	-220 - (+370) +1740	(43) 84	-16 - (+50) + 41	-150 (-200)	-680 - (+190) + 300	6
Sugar cane	-36	-220 - +29	-4	-36 - + 15	-150	-210 - (-)110	9
Dragon fruit	180	90 - 290	36	20 - + 53	60	-1 - + 130	4

10 Nutrient losses during manure storage

The loss of N, P, and K, during manure handling and storage on each farm is shown in Table 16, where it is compared to the nutrient export through selling crops and/or fruit. The table shows that the greatest losses occur on farms with cows and/or buffalos. On three out of ten farms the losses of nutrients during manure storage are more than double the size of the losses due export of farm produce for N and K. For P only two out of ten farms show the double amount of nutrient losses due to manure storage in compare to exports of farm produce.

Table 16: The Table shows the kg of nutrient that is lost during the manure storage compared to the nutrient loss due to all sold farm products, over a period of one year. The red color indicates that manure was sold from the farm

Farm ID	**Animals except chicken**	**N** $kg/year$		**P** $kg/year$		**K** $kg/year$	
		Loss during manure storage	**Export via farm produce**	**Loss during manure storage**	**Export via farm produce**	**Loss during manure storage**	**Export via farm produce**
1	Buffalo, Pig	562	62	48	9.1	747	108
2	Cow, pig	238	312	15	45	616	527
3	Cow, pig	215	8.7	7.3	5.5	397	10.5
4	Cow, duck	54	62	3.5	9.1	107	108
5	Goat	-18	222	-19	31	-36	407
6	Pig	29	106	3.0	16	9.4	151
7 [1]	Pig, (Cow)	-1.8	23	-7.4	1.8	-32	18
8	Buffalo, cow, pig, duck	272	38	23	5.6	541	44
9	Duck	265	605	-456	605	93	148
10	Pig	35	151	-0.58	22	4.9	262

[1] This farm had four cows for three months, before selling all. The compost used during the following nine months was bought. This means that losses from manure storage only occur for three months.

11 The amount of added fertilizer and its nutrient content

Table 17 shows that the use of compost varied across the farms between 0.9 % and 90 % of the total use of fertilizers. Generally, compost accounted for more than 50 % of the used fertilizers. Added compost varied between 20 kg/ha/year and 10 940 kg/ha/year. Added mineral fertilizers varied between 640 kg/ha/year and 2100 kg/ha/year. The farms with the highest use of mineral fertilizers also generally have the highest surplus values for each element (N, P, and K). Farm number 9 is an exception as it used fewer mineral fertilizers but still has the highest surplus values. These values can be explained by the heavy usage of nutrient-rich manure (Appendix B), as a result of a large number of animals and the fact that most of the animal feed was bought. This combined with a very low harvest gave the high surplus values on the farm. There was an indication of higher K values with a more intense use of compost. However, no clear patterns between the use of compost and the nutrient balances in Table 17 and Table 14 were revealed.

Table 17: the table shows the total amount of added fertilizers in kg/ha/year and % of used fertilizers that consist of compost.

	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
The total amount of added organic and mineral fertilizers [kg/year]	3560	12 720	16 740	990	5970	4780	2580	4170	4730	5600
Added organic and mineral fertilizers per area [kg/ha/year]	2590	4010	12 180	1210	3240	3340	2120	3450	8130	2970
% compost used	32	83	90	31	72	0.9	50	81	89	60
Added compost [kg/ha/year]	1170	3340	10 940	380	2340	1670	20	2810	7250	1800
Added mineral fertilizers [kg/ha/year]	1743	680	1240	840	900	1670	2100	640	890	1170

Table 18 shows the total kg applied N, P, and K from mineral fertilizers and compost respectively. Kg applied N/ha from mineral fertilizers ranges between 60 and 360 kg N/ha, applied kg P/ha from mineral fertilizers ranges between 5 and 150, and applied kg K/ha ranges between 8 and 58 kg. For the compost, applied kg N/ha ranges between 0.39 and 59, applied kg P/ha between 0.27 and 93, and applied kg K/ha between 0.29 and 64.

Table 18: Kg applied N, P and K per ha from mineral and organic fertilizer

Farm number	Type of fertilizer, mineral (M) / Compost (C)	Kg N/ha/year	Kg P/ha/year	Kg K/ha/year
1	M	170	48	46
1	C	7.1	2.3	4.7
2	M	110	27	74
2	C	14	16	6
3	M	170	26	90
3	C	39	18	1.4
4	M	160	20	77
4	C	2.1	1.4	3.5
5	M	140	35	85
5	C	23	12	24
6	M	290	58	150
6	C	0.39	0.27	0.29
7	M	360	40	26
7	M	20	10	15
8	M	120	14	37
8	C	27	11	24
9	M	60	8	5
9	C	59	93	64
10	M	180	40	70
10	C	12	5	17

12 Discussion

12.1 Advantages and sources of variability when using a SPAD 502

When estimating the N-value of the grass on the fields a handheld SPAD 502 meter was used. The advantage of using this method is that the measurements are quick to make. This makes it useful when taking multiple samples (Loh et al., 2002). As the study required over 300 samples, the SPAD 502 was a good choice of method. Additionally, the method does not harm or destroy the plant and thus the study object. The SPAD meter was originally used to measure N management in rice. However, today the SPAD meter is used also on other major crops. Since the meter shows an excellent correlation between the N status of the crop and the chlorophyll content, specifically in maize, wheat, and rice, it is today widely accepted in the agronomy sector (Loh et al., 2002).

However, there are some sources of variability in the SPAD meter. The time of the year when measurements are carried out can cause variations in correlation. There are many reasons why the relationship between N and chlorophyll might differ throughout the year. One reason is that the plant during spring may contain free NO_3^- in vacuoles that have not yet been transported to other sinks. This nitrogen is non-chlorophyll related and will therefore not be considered in the N-value given by the SPAD meter. The SPAD meter will register a lower N-reading than what the leaf contains. The leafs' physiological age is contributing to this effect. As the leaf ages, the activity of the enzyme nitrate reductase that controls NO_3^- reduction and assimilation decrease rapidly. As a result of this, it can be assumed that older leaves contain more N as NO_3^- (Loh et al., 2002). Another source of error comes from sampling difficulties. As the precision is affected by the thickness of the leaf, different leaves, having variability in leaf thickness will unavoidably contribute to variability in the SPAD-meter values (Loh et al., 2002). Given these sources of variability, the major reason to not use the SPAD-meter is most likely to be due to measuring errors. The field study was carried out during the fall. Furthermore, the grass is assumed to be young, as it is used as fodder grass in most of the fields. The biggest error is therefore likely to come from the fields where the grass is not harvested, as a result of older and thicker leaves (Loh et al., 2002). The method is still reasonable as it is an easy method when used for many samples, like in this case.

12.2 N concentrations estimated from SPAD values

The N concentration of the grass in the study area had previously been measured to be 1.05 % [2]. These values come from trials with grass, maize, and fruit trees in Son La. Those grass strips were unfertilized. When comparing with the values in Table 2, grass from seven out of 13 of the fields in Son La had higher N concentrations while eight fields had lower values. Based on this the values seem reasonable. The unfertilized grass strips generally got slightly lower values, but the N offtake by the grass was still considerable. This support the theory that the grass strips can contribute to preventing nutrient losses.

As mentioned by Loh et al. (2002) the SPAD meter is today widely used on major crops, which should make it a useful tool to estimate and test the N concentration in guinea grass. In Vuolo et al., (2012) the linear relationship between the amount of chlorophyll and the SPAD value was tested in grass leaves. The result showed a linear relationship. Figure 3 shows that the analysis of guinea leaves had a similar linear relationship. The R-value of 0.975 in figure 3 shows that the estimated N concentrations given from using the SPAD meter should give a result close to the correct value.

12.3 The farm gate balances

According to a study made outside of Hanoi, Vietnam the average balance was positive for all elements (N, P, and K) on each farm (Khai et al., 2007). The study reported a surplus that ranged between 85 to 882 kg/ha/year for N, 109 - 196 kg/ha/year for P, and 20 -306 kg/ha/year for K. In the result of this study (Table 14) all the farms but one showed results for N within the same span. The only one which does not shows a surplus value of 32 kg/ha/year N, which only differs by 53 kg/ha/year N. None of the farms in this study show a value as high as 882 kg/ha/year N. The

[2]Thuong, Pham Huu, ICRAF Hanoi, Vietnam, personal communication

highest value is 580 kg/ha/year N.

The result of this study in terms of P differs from the previously mentioned study. The values from this result range between -680 and 53 kg/ha/year P (16-53 without the outlier). These values are much lower than the values shown in the study from 2007. The lower values indicate that less P would be lost due to runoff, leaching, or erosion. However, the farms in the study from Khai et al., (2007) were made on flat land, while this study was made on sloping land.

The values for K differ the most. The results of this study show values between -130 kg/ha/year and 220 Khai et al., (2007) found the lowest surplus balances for K, it did not contain any negative balances. This indicates a high impact of using grass strips as a part of the AF-system, as it removes a lot of the plant-available K (Bruce, 1999). The high surplus values in this study seem to be linked to heavy usage of mineral fertilizers (Table 17).

12.4 Nutrient balance in regards to grass strips and fertilization habits

It can be seen in Table 15 that in the sole maize system, the K balance is closer to zero, while the N balance was strongly positive. This indicates that farmers add too many kg of N-rich fertilizers to the sole-cropped maize fields. Furthermore, in the present (additional) systems a surplus of N was applied in all systems where the grass was not part of the system, indicating that excessive fertilization of N occurs on all plants.

The mean balances of N and P decrease (less accumulation occurs) as the grass is added to the AF practice with maize (Table 15). For K however, the values went from positive (i.e accumulation) to negative (i.e potential mining). This indicates that the grass contributes to in particular depleting the soil from K in these systems where K fertilization is sparing. Negative balances of N, P, and K can also be seen in fields with sole-cropped sugarcane (Table 15). The two farms with the highest positive N - balance only has one field with fodder grass, with 1000 m^2 or less. These farms furthermore have no sugarcane fields. This reinforces the theory that grass species absorb nutrients. It is generally known that grass species have great potential to absorb nutrients, especially K (Bruce, 1999). Using grass strips as a means to prevent erosion shows the potential to also prevent nutrient losses (Do et al., 2023; Thelberg & Sjödell, 2020). However, the result of this study shows indications that it could also contribute to nutrient mining, especially in the case of K. However, the nutrient uptake from the soil decreases when the amount of plant available nutrients in the soil decreases, and the annual deficits can thus be expected to decrease over time (given the same fertilizer rate).

The accumulation of N, P, and K increases when adding trees to the system, suggesting that farmers fertilize the trees a lot. Table 15 shows that the nutrient balance for N, P, and K is more positive in fields with fruit trees and maize than in fields with sole-cropped maize. Generally, the farmers add fertilizers to the plants divided into two or three applications. Although applying fertilizers at different times increase the number of nutrients absorbed, the amount of added fertilizers is still too high.

12.5 Hypotheses of the study

Based on the previous discussion the hypothesis that states that grass strips along the contour capture nutrient lost from the plot area above and decrease the overall loss of nutrients is supported. Although as mentioned, it can also contribute to nutrient mining in terms of K. Furthermore, the idea of the project was to grow unfertilized grass strips to reduce erosion and reduce nutrient leaching [3]. However, despite recommendations from the project, some farmers add fertilizers to increase the grass yield. The farms that did not fertilize the grass did not use the grass to a great extent. It is due to this difficulty to analyze the hypothesis that high grass production and protein content is supported in spite of no direct fertilization.

During the field visit, it was understood that compost is added to each tree individually with little differences in rates due to distance from the homestead. Nutrient losses on the surveyed farms do therefore not occur as a result of uneven distribution of compost, as the hypothesis states. It rather occurs due to nutrient losses during manure handling, as well as from the fields. The loss from the fields occurs when the fertilization highly exceeds the plant's need and the soil´s storage capacity.

12.6 Nutrient losses from manure during storage

Generally, the result shows that the nutrient losses occurring during storage account for a notable part of the nutrient loss within the farm (table 16). As can be seen in the result, the manure storage on the surveyed farms is frequently lacking sealed ground, walls, or roof on at least one part of the storage area. Much of the nutrient losses seem to occur during second storage (or first for poultry) due to exposure to rain. When water enters the storage location it causes nutrient leaching. Adding sealed roofs to all locations where manure or compost is stored would reduce nutrient losses to a great extent. It was shown in a study of smallholder crop-livestock systems in Kenya that piles of manure stored without a roof lost more nutrients than those stored under a roof (Tittonell et al., 2010).

It is the case for all farms that pigs are never free grazing, while the other animals are either given the possibility to free graze or taken for ”walks”. Free grazing means extra manure in the stable compared to the feed given, meaning nutrients are brought into the nutrient system of the farm (Tittonell et al., 2010). During the interviews, the farmers were not asked how much grass (or other crops) the animals feed during the time of free grazing. Due to this, the extra feed was not taken into account in the calculations. Leaving out the additional feed can give data that show more nutrients in the compost than in the fodder that the farmer gives them, which is most likely the reason for the apparent accumulation of nutrients that is shown on some farms in Table 16. It was due to this difficulty to calculate the exact loss of nutrients for animals other than pigs. It can be assumed, that the values for farms housing only pigs and no cows or buffalos, give more trustworthy data. However, although the data indicate large losses during storage and handling, they cannot support the hypothesis that nutrient losses from the manure storage (in the case of pig manure) are at least as big as the export via farm produce. For cow, goat, and buffalo manure this could not be tested. The example of free grazing can be seen in the result from farm 5. This farm suggests an accumulation of nutrients during storage, which is not possible. This indicates

[3]Nguyen, La 2023 ICRAF Hanoi, Vietnam

that the goats get their main source of fodder, and thereby its source of N, P, and K from free grazing. It seems to be the case, that animals feed more than reported in the surveys, and that the harvested fodder grass does not account for the entire amount of grass-fed to the animals.

In the cases of farms 9 and 7, the negative values depend on sold products. Farm 7 sold all their cows. This does not mean that there were no nutrient losses during manure storage. At farm 9, the most likely reason is the P-value in duck manure, which seems unreasonably high. As the farm produces high quantities of compost, an error in the P values in manure would give high variations in the nutrient balance. This shows the difficulties in calculating nutrient losses during manure storage.

On the farms with ponds, the manure storage was located uphill in regards to the pond. The nutrient leaching from the manure storage is therefore likely to end up in the water. As the water is used to irrigate the fields, some of the lost nutrients could potentially return to the system. On some of the farms, the manure storage was located in connection to the field or home garden, supplying nutrients directly to the plants. In these cases, however, the nutrient leaching is much greater than the nutrient uptake by the nearby growing plants. Furthermore, all farmers still fertilize their home gardens with (usually) chicken manure, which is very high in nutrients already.

12.7 guinea Grass as an invasive species

The cut-and-carry system used on the farms depends on the grass being cut and managed, as it will otherwise spread and could potentially become a problem. At many farms, the grass was not used for the animals or only used to a small extent. At these farms, the grass had spread and no rows existed (Table 2).

The guinea grass is not native to Vietnam. However, despite this, it is widely used due to its success as a forage species. The forage grass has undergone several major breeding programs to produce a species that contains the most desirable traits for forage production. As the guinea grass is not native to the country, using it as a forage grass will impact the biodiversity and the local ecosystem. Globally the guinea grass belongs to the high-risk invasive species. Meanwhile, the use of guinea grass is important for economic growth. It belongs to the forage grasses in the subtropical and tropical regions that are of most importance (Rhodes et al., 2021; Viana et al., 2014). Only because a species is non-native and hence invasive, it does not necessarily mean a major problem in all cases. However, in the case of guinea grass, the species possess the same traits as previous species with successful invasiveness. It spreads rapidly, has a very high reproduction potential, and has a long life. In addition, the plant can overgrow and shade other species, making it out-compete native grass and plants, thus creating mono dominance. This mono dominance reduces species richness and/or abundance (Rhodes et al., 2021). In areas where the guinea grass is not being grazed or in other ways managed it spreads easily, becoming an unwanted weed. This is especially a problem in sugarcane fields (Rhodes et al., 2021), which are common in the study area.

In most of the studied farms, the need for forage grass is low, resulting in low maintenance of the grass rows. It was observed in the fields, as well as reported by the farmers, that much of the grass had spread outside the original rows. Clear rows could be found only on farms with a high number of animals. Additionally, the grass was fertilized in most cases. The result is a rapidly spreading grass that risks becoming a major problem in the future if not maintained properly.

12.8 Sources of errors in calculations and assumptions

When calculating the nutrient balance and nutrient losses, some of the used concentrations of N, P, and K were taken from the literature. As the nutrient concentration varies between species, the literature values used in the calculations are sources of insecurities in the results. To obtain better values, all organic materials should be brought in for analysis at a lab, however, there was no funding to do so.

This year all the farms faced low temperatures during December to February season, resulting in low yield from the fruit trees. This means that normally the nutrient export is higher. The balance would therefore be less positive than what is shown in the results and the nutrient losses would normally be higher.

The highest grass harvest was stated at farm 1, with 95 kg harvested grass per day (table 2). When visiting the fields the grass strips were indeed clear, well-maintained, and recently cut. However, the yield seems oddly high in comparison to other farms. During the interviews, other farmers stated that they only harvest the grass strips during the rainy season. During the dry season they feed animals with crop residue such as from sugar cane. Farm 1 on the other hand has not stated any use of other types of fodder than forage grass all year. It could be that the harvest level is as high as stated, but it is also likely that there was a miscommunication during the interview. It should be emphasized that the kg of harvest stated on the farms is counted as harvest per day during one year, although the harvest was (on the other farms) only taken during six months. This means the actual harvest per day during harvest season was twice as high for all farms but farm 1.

The stated grass usage in the calculations is assumed to be evenly distributed over the fields, based on the area of grass on each field. This is not necessarily true in all cases. The farmers also estimated the area of grass based on how much grass was originally planted. This was inaccurate in several cases, as the grass had spread on many of the fields.

The probably highest cause of error in the report is human error. Due to estimations made by the farmers, the given values can vary from the actual values more or less between the various farms. As the limited study time did not permit to test of the stated values, the information given in the surveys was never double-checked.

One possible error which could not be checked due to late discovery was the P value of the duck manure at farm 9. The value seems unreasonably high and is probably the main reason for the high deficit of P seen in the P balances on that farm.

When calculating nutrient losses during manure storage the manure that accounts for the nutrient outflow is based on the stated use of compost rather than the total kg of ready-to-use compost produced within a year. It is assumed in the report, and in the calculation, that all ready-to-use compost is used on the fields during the year. There may, however, be deviations.

When calculating the nutrient balances on the field, nutrient losses due to erosion, runoff, leaching, or gas losses (in the case of N) were not taken into account. It can be seen in several studies that nutrient losses occur on the test site (Thelberg & Sjödell, 2020) and that an AF system decreases nutrient loss through sediment movement. In the study from Do, (2023) nutrient losses through erosion during 2020 were measured to be 1.4 kg/ha N, 0.3 kg/ha P, and 7.3 kg/ha K for the AF system. For the sole maize system, the nutrient losses through erosion were measured to be 4.2 kg/ha N, 0.8 kg/ha P, and 22 kg/ha K (Do et al., 2023). To give a better estimation of the total nutrient balance, such numbers should be added to the calculations. However, when comparing with the overall farm gate balances, the values for N and P would not change the balances to a great extent. For K on the other hand, the nutrient losses due to erosion are bigger and would show a greater impact on the overall balance equation.

13 Example of studies that could be made following this report

As guinea grass is an invasive species, using native grass species or fodder bushes as a barrier could be a solution. Although the problem with K depletion could remain. The used crop should preferably be of use both in terms of fodder production and erosion control. A further study could look at another type of vegetative barrier that does not have invasive properties.

Due to the time constraints of this study, it was not possible to do detailed calculations of nutrient losses during the manure storage. Nevertheless, an estimation was made based on nutrient inflow and outflow through the compost. However, the information on nutrient intake in terms of feed given to the animals was not sufficient to do an estimation with high precision. This study could not include the fodder consumed through free grazing. Future surveys should include questions such as ”How much time do the animals spend free grazing?” and ”What do the animals eat while free grazing” as well as questions regarding the proportion of plants eaten and if the farmers stop and let the animal graze or not. This way the calculation could be made based on estimations of how much nutrients they take up while free grazing. Additionally, it should preferably include an estimation of how much manure, and thus nutrients, is being lost while the animal grazes.

Additionally, I recommend that further studies are made on nutrient loss during manure storage. The result of this study can account for high losses, however, as the number of animals and amount of given feed varies greatly, so do the losses. A study looking at more similar conditions, the number of animals as well as amount and type of feed given, would provide a better and more reliable result on the nutrient losses during manure storage.

14 Conclusions

The main objective of this study was to locate and quantify the sinks and sources of nutrients within ten farms in Northwest Vietnam. Through this study the research questions could be answered as follow;

- The overall balances of nutrients on the farms ranged between 32 to 580 kg/ha/year for N, 16 and 53 kg/ha/year for P, and between -130 and 220 kg/ha/year for K.

- The results imply that using contouring grass strips is an effective way to reduce nutrient losses, but the grass strips risk causing K mining if not fertilized properly. In sugarcane fields, nutrient deficits occurred for all three nutrients. However, the farmers seemed to fertilize all crops but sugarcane with a surplus of N and P. The farmers should therefore be advised to buy fertilizer with a higher proportion of K, allowing them to reduce the overall fertilizer rates.

- On farms with few or no grass-feeding animals, the grass had spread outside of the rows. Guinea grass is an invasive species, and risks mining the soil of its K- storage, and it should therefore be considered trying another form of erosion control on farms that do not have grass-feeding animals.

- High nutrient losses occurred during manure storage in all cases. The highest nutrient losses seemed to occur during the second storage, which is generally a pile outside of the pen. This pile usually lacked sealed ground, walls, and roof to protect it from leaching or erosion due to runoff water. Additional data need to be collected to generate results with higher precision about the nutrient losses from cow, buffalo, and goat manure.

References

Abbas, M. (2012). A Quantitative Analysis And Comparison Of Nitrogen, Potassium And Phosphorus In Rice Husk And Wheat Bran Samples. *Pure and Applied Biology*, vol. 1(1), pp. 14–15. https://doi.org/10.19045/BSPAB.2012.11003

Adler, G., Ndzarek, A., & Tórz, A. (2019). Concentrations of selected metals (NA, K, CA, MG, FE, CU, ZN, AL, NI, PB, CD) in coffee. *Zdravstveno Varstvo*, vol. 58(4), pp. 187–193. https://doi.org/10.2478/SJPH-2019-0024

Al-Kaisi, M., & Helmers, M. (2008). *Heavy Rain, Soil Erosion and Nutrient Losses* (tech. rep.). Iowa State University. Available from: https://dr.lib.iastate.edu/entities/publication/571183b7-ca1d-402b-aa95-13edc6e0ff5b

Amar, A. (2012). Nitrogen content and dry-matter digestibility of guinea and sabi grasses as influenced by tree legume canopy. *Majalah Ilmiah Peternakan*, vol. 7.

ASEAN. (2014). ASEAN Food Composition Database. Available from: http://www.inmu.mahidol.ac.th/aseanfoods/download/books/dl1.php?file=A1

Atangana, A., Khasa, D., Chang, S., & Degrande, A. (2014). Tropical agroforestry. *Tropical Agroforestry*, pp. 1–380. https://doi.org/10.1007/978-94-007-7723-1/COVER

Bergström, L., & Dahlin, S. (2005). Växtnäringshushållning i svenska odlingssystem – med och utan djur. *Rapport MAT21 nr 10/2005*.

Bruce, R. C. (1999). Sustainable nutrient management in sugarcane production short course : course manual, 25-26 May, 1999, Willows Golf Club, Townsville, p. 116. Available from: https://www.researchgate.net/publication/275655754_Sugarcane_Nutrition_and_Fertilization

Celik, I., Ortas, I., & Kilic, S. (2004). Effects of compost, mycorrhiza, manure and fertilizer on some physical properties of a Chromoxerert soil. *Soil and Tillage Research*, vol. 78(1), pp. 59–67. https://doi.org/10.1016/J.STILL.2004.02.012

Corrêa, R. C., Peralta, R. M., Haminiuk, C. W., Maciel, G. M., Bracht, A., & Ferreira, I. C. (2016). The past decade findings related with nutritional composition, bioactive molecules and biotechnological applications of Passiflora spp. (passion fruit). *Trends in Food Science Technology*, vol. 58, pp. 79–95. https://doi.org/10.1016/J.TIFS.2016.10.006

Council, N. R. (2003). Air Emissions from Animal Feeding Operations: Current Knowledge, Future Needs. *Air Emissions from Animal Feeding Operations*, Appendix D. https://doi.org/10.17226/10586

Czapar, G. F., Laflen, J. M., McIsaac, G. F., & McKenna, D. P. (2005). Effects of Erosion Control Practices on Nutrients losses. Available from: https://wrl.mnpals.net/islandora/object/WRLrepository%5C%3A969/

Dahlin, A., Emanuelsson, U., & McAdam, J. (2005). Nutrient management in low input grazing-based systems of meat production. *Soil Use and Management*, vol. 21(1), pp. 122–131. https://doi.org/10.1111/J.1475-2743.2005.TB00116.X

Daleke, P. (2021). Vietnam – Geografi och klimat — Utrikespolitiska institutet. Retrieved March 20, 2022, from available from: https://www.ui.se/landguiden/lander-och-omraden/asien/vietnam/geografi-och-klimat/

Do, V. H., La, N., Bergkvist, G., Dahlin, S., Mulia, R., Nguyen, V. T., & Öborn, I. (2023). Agroforestry with contour planting of grass contributes to terrace formation and conservation of soil and nutrients on sloping land. *Agriculture, Ecosystems Environment*, vol. 345, p. 108323. https://doi.org/10.1016/J.AGEE.2022.108323

Doyle, P. T., Devendra, C., & Pearce, G. R. (n.d.). Rice straw as a feed for ruminants international development program of Australian universities and colleges.

Fairhurst, T., Witt, C., Buresh, R., & Dobermann, A. (2007). Edited by Nutrient management Nutrient deficiencies Mineral toxicities Tools and information A Practical Guide to Nutrient Management Rice R e v i s e d 2 0 0 7 E d i t i o n.

FAO. (1991). List of commonly used organic manure. Available from: https://www.fao.org/fileadmin/user_upload/affris/docs/Rohu_Labeo/English/table_5.htm

Golden, L. E., & Ricaud, R. (1963). LSU Digital Commons The nitrogen, phosphorus and potassium contents of sugar cane in Louisiana The Nitrogen, Phosphorus and Potassium Contents of Sugar Cane in Louisiana. Available from: http://digitalcommons.lsu.edu/agexp/382

Hafid, H., Napirah, A., Nuraini, Febiano, M. F., & Ananda, S. H. (2021). Slaughter weight, carcass and giblets percentage of broiler chicken with addition of Indigofera zollingeriana leaves in feed. *IOP Conference Series: Earth and Environmental Science*, vol. 788(1), p. 012184. https://doi.org/10.1088/1755-1315/788/1/012184

Hayse, P. L., & Marion, W. W. (1973). Eviscerated Yield, Component Parts, and Meat, Skin and Bone Ratios in the Chicken Broiler. *Poultry Science*, vol. 52(2), pp. 718–722. https://doi.org/10.3382/PS.0520718

Hifnalisa, Karim, A., Fazlina, Y. D., Manfarizah, Jufri, Y., & Sabrina, T. (2022). The nutrient content of N, P, K in Andisols and Arabica coffee leaves in Bener Meriah Regency, Indonesia. *IOP Conference Series: Earth and Environmental Science*, vol. 951(1). https://doi.org/10.1088/1755-1315/951/1/012014

Hoang, L., Roshetko, J. M., Huu, T. P., Pagella, T., & Mai, P. N. (2017). Agroforestry - The Most Resilient Farming System for the Hilly Northwest of Vietnam. *International Journal of Agriculture System*, vol. 5(1), pp. 1–23. https://doi.org/10.20956/IJAS.V5I1.1166

Hoekstra, P. F., & Hannam, C. (2017). VEGETATIVE BUFFERS A Report to the Agriculture and Agri-Food Canada Multi-stakeholder Forum (Mitigation Working Group) for Neonicotinoids.

Honig, A. C., Inhuber, V., Spiekers, H., Windisch, W., Götz, K. U., Strauß, G., & Ettle, T. (2022). Content and gain of macro minerals in the empty body and body tissues of growing bulls. *Meat Science*, vol. 194, p. 108977. https://doi.org/10.1016/J.MEATSCI.2022.108977

Ibáñez, M. A., de Blas, C., Cámara, L., & Mateos, G. G. (2020). Chemical composition, protein quality and nutritive value of commercial soybean meals produced from beans from different countries: A meta-analytical study. *Animal Feed Science and Technology*, vol. 267. https://doi.org/10.1016/J.ANIFEEDSCI.2020.114531

Irshad, M., Eneji, A. E., Hussain, Z., & Ashraf, M. (2013). Chemical characterization of fresh and composted livestock manures. *Journal of soil science and plant nutrition*, vol. 13(1), pp. 115–121. https://doi.org/10.4067/S0718-95162013005000011

Jordbruksverket. (2020). Övergödning och läckage av växtnäring - Jordbruksverket.se. Retrieved March 20, 2022, from available from: https://jordbruksverket.se/jordbruket-miljon-och-klimatet/overgodning-och-lackage-av-vaxtnaring

Jouquet, E., Bloquel, E., Doan, T. T., Ricoy, M., Orange, D., Duc, T. T., Jouquet, E., Bloquel, E., Ricoy, M., Orange, D., & Rumpel, C. (2011). Do Compost and Vermicompost Improve Macronutrient Retention and Plant Growth in Degraded Tropical Soils? *Compost Science and Utilization*, vol. 19(1), pp. 15–24. https://doi.org/10.1080/1065657X.2011.10736972

Khai, N. M., Ha, P. Q., & Öborn, I. (2007). Nutrient flows in small-scale peri-urban vegetable farming systems in Southeast Asia—A case study in Hanoi. *Agriculture, Ecosystems Environment*, vol. 122(2), pp. 192–202. https://doi.org/10.1016/J.AGEE.2007.01.003

Kleczek, K., Wilkiewicz-Wawro, E., Wawro, K., & Makowski, W. (2007). Effect of body weights of day-old Muscovy ducklings on growths and carcass traits. *Archives Animal Breeding*, vol. 50(2), pp. 204–213. https://doi.org/10.5194/AAB-50-204-2007

Konica Minolta. (2009). Chlorophyll meter SPAD-502, pp. 2–2.

La, N., Catacutan, D. C., Nguyen, M., Van Hung, D., & Australian Centre for International Agricultural Research. (2019). Agroforestry for livelihoods of smallholder farmers in northwest Vietnam : final report, p. 58. Available from: https://www.aciar.gov.au/publication/technical-publications/agroforestry-livelihoods-smallholder-farmers-northwest-vietnam-final-report

Lee, J.-T., Kim, H.-D., Lee, S.-D., & Ro, C.-W. (2012). Evaluation of Composted Pig Manure and Organic Fertilizer for Organic Onion Production in Paddy Soil. *Korean Journal of Horticultural Science and Technology*, vol. 30(2), pp. 123–128. https://doi.org/10.7235/HORT.2012.11086

Loh, F. C., Grabosky, J. C., & Bassuk, N. L. (2002). Using the SPAD 502 meter to assess chlorophyll and nitrogen content of benjamin fig and cottonwood leaves. *HortTechnology*, vol. 12(4), pp. 682–686. https://doi.org/10.21273/HORTTECH.12.4.682

Luu, T. T. H., Le, T. L., Huynh, N., & Quintela-Alonso, P. (2021). Dragon fruit: A review of health benefits and nutrients and its sustainable development under climate changes in Vietnam. *Czech Journal of Food Sciences*, vol. 39(2), pp. 71–94. https://doi.org/10.17221/139/2020-CJFS

Maass, J. M., Jordan, C. F., & Sarukhan, J. (1988). Soil Erosion and Nutrient Losses in Seasonal Tropical Agroecosystems Under Various Management Techniques. *The Journal of Applied Ecology*, vol. 25(2), p. 595. https://doi.org/10.2307/2403847

Macadamias, O. (n.d.). Tips on drying macadamia nuts. Retrieved November 22, 2022, from available from: https://www.ohiwamacadamias.co.nz/info/drying-nuts

Maselesele, D., Ogola, J. B., & Murovhi, R. N. (2021). Macadamia Husk Compost Improved Physical and Chemical Properties of a Sandy Loam Soil. *Sustainability 2021, Vol. 13, Page 6997*, vol. 13(13), p. 6997. https://doi.org/10.3390/SU13136997

Millet, S., Aluwé, M., Van Den Broeke, A., Leen, F., De Boever, J., & De Campeneere, S. (2018). Review: Pork production with maximal nitrogen efficiency. *Animal*, vol. 12(5), pp. 1060–1067. https://doi.org/10.1017/S1751731117002610

Moore, P., & Botha, F. (2014). *Sugarcne Physiologgy Biochemisty and Functional Biology*. John Wiley Sons, Incorporated.

Musa, A. (2009). Nutritional Quality Components of Indigenous Freshwater Fish Species, ¡i¿Puntius stigma¡/i¿ in Bangladesh. *Bangladesh Journal of Scientific and Industrial Research*, vol. 44(3), pp. 367–370. https://doi.org/10.3329/BJSIR.V44I3.4412

Nair, P. K. R., Kumar, B. M., & Nair, V. D. (2021). An Introduction to Agroforestry. *An Introduction to Agroforestry*. https://doi.org/10.1007/978-3-030-75358-0

Nguyen, X. H., & Pham, A. H. (2018). *Assessing Soil Erosion by Agricultural and Forestry Production and Proposing Solutions to Mitigate: A Case Study in Son la Province, Vietnam* (tech. rep.). Hindawi Limited. https://doi.org/10.1155/2018/2397265

Öborn, I., Edwards, A. C., Witter, E., Oenema C, O., Ivarsson, K., Withers, P. J., Nilsson, S. I., & Richert Stinzing, A. (2003). Element balances as a tool for sustainable nutrient management: a critical appraisal of their merits and limitations within an agronomic and environmental context. *European Journal of Agronomy*, vol. 20(1-2), pp. 211–225. https://doi.org/10.1016/S1161-0301(03)00080-7

Öborn, I., Modin-Edman, A. K., Bengtsson, H., Gustafson, G. M., Salomon, E., Ingvar Nilsson, S., Holmqvist, J., Jonsson, S., & Sverdrup, H. (2005). A systems approach to assess farm-scale nutrient and trace element dynamics: A case study at the Öjebyn dairy farm. *Ambio*, vol. 34(4-5), pp. 301–310. https://doi.org/10.1579/0044-7447-34.4.301

Perry, T. W. (1984). Poultry. *Animal Life-cycle Feeding and Nutrition*, pp. 225–255. https://doi.org/10.1016/B978-0-12-552060-7.50023-1

Ponnanaperuma, F. (1984). Straw on a source of nutrients for wetland rice. https://doi.org/10.3/JQUERY-UI.JS

Rachmat, M., & Nguyen, M. (2021). *Diversity of agroforestry practices in Viet Nam*. ICRAF. Available from: https://www.researchgate.net/publication/350313512_DIVERSITY_OF_AGROFORESTRY_PRACTICES_IN_VIET_NAM

Rachmat, M., & Nguyen, M. (2022). *Diversity of agroforestry practices in Viet Nam by nminh.icraf - Issuu*. Available from: https://issuu.com/nminh.icraf/docs/bk00232-21

Ramírez-Rodríguez, Y., Martínez-Huélamo, M., Pedraza-Chaverri, J., Ramírez, V., Martínez-Tagüeña, N., & Trujillo, J. (2019). Ethnobotanical, nutritional and medicinal properties of Mexican drylands Cactaceae Fruits: Recent findings and research opportunities. https://doi.org/10.1016/j.foodchem.2019.126073

Rhodes, A. C., Plowes, R. M., Goolsby, J. A., Gaskin, J. F., Musyoka, B., Calatayud, P. A., Cristofaro, M., Grahmann, E. D., Martins, D. J., & Gilbert, L. E. (2021). The dilemma of Guinea grass (Megathyrsus maximus): a valued pasture grass and a highly invasive species. *Biological Invasions*, vol. 23(12), pp. 3653–3669. https://doi.org/10.1007/S10530-021-02607-3/FIGURES/3

Richards, T. E., Kämper, W., Trueman, S. J., Wallace, H. M., Ogbourne, S. M., Brooks, P. R., Nichols, J., & Bai, S. H. (2020). Relationships between Nut Size, Kernel Quality, Nutritional Composition and Levels of Outcrossing in Three Macadamia Cultivars. *Plants*, vol. 9(2). https://doi.org/10.3390/PLANTS9020228

Seerley, R. (1991). Major Feedstuffs Used in Swine Diets. *Swine Nutrition*, pp. 451–481. https://doi.org/10.1016/B978-0-409-90095-8.50033-6

Thelberg, H., & Sjödell, B. (2020). Impact of agroforestry on soil loss mitigation in the sloping land of Northwest Vietnam. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:uu:diva-411180

Thiyageshwari, S., Gayathri, P., Krishnamoorthy, R., Anandham, R., & Paul, D. (2018). Exploration of rice husk compost as an alternate organic manure to enhance the productivity of blackgram in typic haplustalf and typic rhodustalf. *International Journal of Environmental Research and Public Health*, vol. 15(2). https://doi.org/10.3390/ijerph15020358

Tittonell, P., Rufino, M. C., Janssen, B. H., & Giller, K. E. (2010). Carbon and nutrient losses during manure storage under traditional and improved practices in smallholder crop-livestock systems-evidence from Kenya. *Plant and Soil*, vol. 328(1), pp. 253–269. https://doi.org/10.1007/S11104-009-0107-X/FIGURES/10

Truong, P. N. V., & Loch, R. (2004). VETIVER SYSTEM FOR EROSION AND SEDIMENT CONTROL.

USDA. (2012). FoodData Central -Chicken, broiler or fryers, breast, skinless, boneless, meat only cooked braised. Retrieved January 27, 2023, from available from: https://fdc.nal.usda.gov/fdc-app.html#/?component=0

Varghese Jose, J., & Nabi, M. (2022). *Sustainable plant nutrition molecular interventions and advancements for crop improvement* (T. Aftab & K. R. Hakeem, Eds.). Academic Press. Available from: http://p5070-www.sciencedirect.com.ezproxy.its.uu.se/book/9780443186752/sustainable-plant-nutrition

Viana, M., Silva, I., Freire, F., Ferreira, M., Costa, É., Mascarenhas, M., & Ferreira França Teixeira, M. (2014). Production and nutrition of irrigated tanzania guinea grass in response to nitrogen fertilization. *Revista Brasileira de Zootecnia*, vol. 43, pp. 238–243. https://doi.org/10.1590/S1516-35982014000500003

Watson, C., Öborn, I., Eriksen, J., & Edwards, A. (2008). Perspectives on nutrient management in mixed farming systems. *Soil Use and Management*, vol. 21(1), pp. 132–140. https://doi.org/10.1111/J.1475-2743.2005.TB00117.X

WorldBank. (2022). *2022 Vietnam Poverty and Equity Assessment Report* (tech. rep.). Available from: https://www.worldbank.org/en/country/vietnam/publication/2022-vietnam-poverty-and-equity-assessment-report

Yao, Y., Dai, Q., Gao, R., Gan, Y., & Yi, X. (2021). Effects of rainfall intensity on runoff and nutrient loss of gently sloping farmland in a karst area of SW China. *PLOS ONE*, vol. 16(3), e0246505. https://doi.org/10.1371/JOURNAL.PONE.0246505

A questionnaire

QUESTIONNAIRE REGARDING NUTRIENT MANAGEMENT ON FARMS IN NORTHWEST VIETNAM

The reason for this questionnaire is to collect information needed in a master thesis. The master thesis is part of a bigger project between the organizations SFRI, ICRAF and SLU. The master thesis is researching where the major nutrient losses (specifically Nitrogen) may occur within the farm, and what changes/action can be made to limit the Nitrogen losses. This would contribute to a better economy at the farm as well as improve limnic conditions.

The project requires that information about the nutrient management on the farm is collected, as well as that samples of the nutrient content in the forage grass and the manure is taken. All data that is stored will be used anonymously. The final paper and results can be found if contacting ICRAF: s contact person (La Nguyen). During the time of the project stored info can be accessed through contact person La Nguyen, and you may at any time take back the permission of using the stored data.

My hope for this questionnaire is to collect enough data asses the nutrient flows on the farm. The data will partly be used to find locations in which major nutrient losses may occur; adjustment of practices may give higher nutrient use efficiently and enhanced economy on the farm. They will also be used to find locations where soil fertility might decline over time; these locations may need some fertility management to stay fertile. The result of the data will eventually be used to provide recommendations of how to improve the nutrient management at the farm. This will help farmers generate a better economy and at the same time be more environmentally friendly.

The questionnaire is divided into two parts. Part 1 collects information from each field and part 2 collects information about the remaining part of the farm. In addition, the questionnaire also contains a calendar to provide a timeline for animal and crop production, as well as a sketched map of the farm to provide a drawn figure to show the movement of nutrients within the farm.

Farm-ID is the specific number that the farm has been given as a mean to further refer to the farms anonymously in the report.

Thank you for participating!

KHẢO SÁT VỀ QUẢN LÝ DINH DƯỠNG TRÊN TRANG TRẠI Ở MIỀN BẮC VIÊT NAM

Lý do cho bảng câu hỏi này là để tiến hành thông tin cần thiết cho luận văn thạc sĩ. Luận văn thạc sĩ là một phần của dự án lớn hơn giữa các tổ chức Viện Thổ nhưỡng Nông hóa (SFRI), Trung Tâm nghiên cứu Nông Lâm Kết hợp Quốc tế (ICRAF) và Trường Đại học Nông nghiệp Thụy Điển (SLU). Luận văn thạc sĩ tập trung nghiên cứu nguyên nhân chính gây thất thoát chất dinh dưỡng (cụ thể là Nitơ) xảy ra trong quá trình canh tác và những thay đổi / hành động nào có thể được thực hiện để hạn chế thất thoát Nitơ vì điều này sẽ cải thiện tình trạng thiếu Nitơ cũng như đóng góp vào việc canh tác hiệu quả. Nó giúp quản lý chất dinh dưỡng trong nông hộ môi trường tốt hơn.

Dự án yêu cầu phải thu thập thông tin về quản lý chất dinh dưỡng trong hộ gia đình cũng như lấy mẫu phân tích hàm lượng dinh dưỡng trong cỏ làm thức ăn gia súc và phân chuồng. Tất cả dữ liệu được lưu trữ sẽ được xóa sau khi bài báo đã được xuất bản và nó sẽ không được chia sẻ ra bên ngoài dự án. Bài báo và kết quả cuối cùng có thể được tìm thấy nếu liên hệ với người đại diện (La Nguyễn). Trong thời gian của dự án, thông tin được lưu trữ có thể được truy cập thông qua người đại diện La Nguyễn, và bạn có thể lấy lại quyền sử dụng dữ liệu đã lưu trữ bất cứ lúc nào.

Hy vọng của tôi cho cuộc khảo sát này là có thể thu thập đủ dữ liệu để có thể xây dựng một chu trình quản lý dinh dưỡng trong nông hộ. Dữ liệu sẽ được sử dụng để tính toán sự thất thoát chất dinh dưỡng và tìm ra những vị trí mà sự thất thoát chất dinh dưỡng chính xảy ra. Dữ liệu được thu thập từ một số trang trại trong khu vực và thông tin sẽ được hiển thị ẩn danh trong báo cáo cuối cùng. Các trang trại được đưa vào cuộc khảo sát đã được chọn ra dựa trên việc chúng phù hợp với các yêu cầu của kỹ thuật canh tác mà chúng tôi dự định điều tra. Kết quả của dữ liệu cuối cùng sẽ được sử dụng để đưa ra các khuyến nghị về cách cải thiện việc quản lý chất dinh dưỡng tại trang trại. Điều này sẽ giúp nông dân tạo ra một nền kinh tế tốt hơn và thân thiện với môi trường hơn.

Cuộc khảo sát được chia thành hai phần. Phần 1 thu thập thông tin từ mỗi thửa ruộng/nương của nông hộ và phần 2 thu thập thông tin về phần còn lại của trang trại. Ngoài ra, cuộc khảo sát còn có lịch để cung cấp lịch trình sản xuất vật nuôi và cây trồng, cũng như bản đồ phác thảo của trang trại để cung cấp một sơ đồ thể hiện sự di chuyển của các chất dinh dưỡng trong trang trại.

Farm-ID là con số cụ thể mà trang trại đã được cung cấp như một phương tiện để tham khảo thêm về các trang trại ẩn danh trong báo cáo.

Cảm ơn vì đã tham gia!

QUESTIONNAIRE REGARDING NUTRIENT MANAGEMENT ON FARMS IN NORTHWEST VIETNAM – PART 1

GENERAL QUESTIONS

☐ What is the farm-ID?

☐ What is the field nr?

☐ How big is the farm and its parts (add size to each pen/field and garden on a map)

CROP PRODUCTION AND ROTATION

☐ What cropping system do you use on the field? (Intercropping, sole cropping etc) Please describe the system.

___

___

___

☐ Intercropping is used _______ not used ________

☐ Sole cropping is used _______ not used ________

☐ Is the field a: Paddy field________: uphill field________: garden____________

State the crop(s)/ fruit tree(s) in the field				
State how many rows exist of each crop/tree				
How long is each row?				

How long are the rows?				
What is the cropping distance?				
State unit of harvested crop/fruit. If unit is local, the weight should be stated.				
State unit of sold crop/fruit. If unit is local, the weight should be stated.				

This farm has agroforestry system _____ Non agroforestry system_______

Nutrient inputs

☐ Do you buy mineral fertilizers?
Yes: _____________ No: _____________________

☐ Are additional nutrient sources (bought or from the farm) added to the field? [Examples of such could be mineral fertilizers, compost, manure, etc.]:
Yes: _____________ No: _____________________

If Yes:

Crops receiving the nutrient source			

Type of nutrient sources added (If possible, state specific type of mineral fertilizer if used)			
How much of this nutrient			
source is bought (state amount/ week or year and how many weeks)			
Frequency of applying the nutrient source (How often/ when) (state frequency per crop given the nutrient source)			
How much do you apply to each crop? (State known unit of the dosage)			
What's the average weight of the chosen unit? (This is weight by the interviewer on site each time a local/individual unit is used)			

If mineral fertilizers were used:

☐ What NPK-content does each fertilizer have (give proportion)?

☐ What is the brand/ product names of the used mineral fertilizers? (Add picture if possible)

☐ In case you cannot answer the two questions above: Do you use the same type of mineral fertilizer as your neighbors?

☐ Do you use what the fertilizer dealer recommends for each crop/tree, or do you use one type across, if so which one?

☐ If you fertilize using manure: Do you buy manure?

Yes ____________ No ____________________

If yes:

☐ How much do you buy? State unit per day/ week. If unit is local, weight of unit must be measured and stated.

____

____

☐ How many days/weeks do you buy manure?

____

☐ What is the prize of each fertilizer/ compost/ manure/ etc?

____

____

☐ Do you irrigate the field?

Yes___________ No____________

If yes:

☐ Where is the water taken? [e.g local pond etc]

____

____

____

☐ Does this water source have nutrient inputs of some sort? [e.g connect with river that pass close to compost, manure storage or used for household waste] Describe what kind of nutrient input.

Crop product and outputs

☐ How much of each crop (including fruit) is harvested in a year? (If possible, give answer in kg, local unit or how many rows); if local unit is used, the weight of this unit will be measured by the interviewer.

☐ What proportion/ how much of the harvest is consumed on the farm in kg in a typical year?

☐ Are the non-fruit parts of the trees used as fodder, firewood, building material etc? I.e are any parts removed, or are all left in the field?

QUESTIONNAIRE REGARDING NUTRIENT MANAGEMENT ON FARMS IN NORTHWEST VIETNAM -PART 2

GENERAL QUESTIONS

☐ What is the farm-ID?

☐ State the field numbers that belong to the farm?

☐ How much nutrient sources such as fertilizer/manure/compost/other nutrient source do you buy in total in a year?

CROP RESIDUE

☐ What is the fate of the crop-residues, and how much (proportion or in kg) goes where in a year?

- Burned
- Used as fodder on own farm
- Sold (leaving the premises of the farm)
- Remain on the field
- Used as compost
- Other use:

____

____

☐ If burned:

- When? ____
- What is the reason for burning it?

____

____

____

☐ If removed from field: How is the crop-residue being handled and stored?

- Is there a floor beneath? ____

- If so, what material is the floor made of? ____
- Is the crop residue protected from rain? ____
- What happens with the field until next planting season? __________________________

____

- How long time is it between removing the crop residue and next planting season?

☐ If left on the surface; how, why, and what happens to them? Do they remain at the start of next planting season?

____
____
____
____

Grass and fodder

Grass strips

____

☐ Are you using grass strips on the contours to decrease erosion?

____

☐ What type of grass do you use for the grass strips?

____

☐ What is the fate of that grass?

- Used as fodder on own farm
- Sold (leaving the farm)
- Only for erosion control (not harvested)
- Other uses:

  ____

☐ How much of this grass is used as fodder for the animals? Give answer in units per day/week and how many days/weeks in a year they are given fodder. If local unit is used, the weight of this unit should be measured and stated.

____
____
____

☐ How much of the grass from the grass strips do you sell as fodder (or other uses). State units per year if possible. Use the same unit as above.

____
____

☐ How frequently is this grass harvested, and how much is harvested each time?

____

In case of sole cropping fields with only fodder grass

☐ Do you sell grass from the fields as fodder? If yes; which fields? ____________________

☐ Do you use grass from the fields as fodder? If yes; which fields? ____________________

☐ How many units of grass is harvested on each field in a year? ______________________

☐ How frequently do you harvest the fodder grass in a year? ________________________

☐ How much grass is being harvested each time? _________________________________

☐ How many units of grass is sold in a year? If local unit is used, the unit need to be weight and stated.

____

____

Animal keeping

☐ Do you have animals on the farm? ____

☐ What kind of animals? ____

If you have animals on the farm: please fill in table.

Kind of animal:			
How many adult animals exist on the farm at the beginning of a year (1 January)?			
How many animals are born during in a year?			
How many animals are bought during a year?			
At what age are the animals bought?			
How many animals are being sold each year?			
At what age are the animals sold?			
How many are being slaughtered each year?			
At what age are the animals slaughtered?			

How much product from slaughter and/ or milk etc is sold each year? (If local unit is used, please add weight)			
How much of these products are consumed at the farm?			
What happens to the offal?			

☐ Are the animals free grazing, tethered, in a pen or housed? Does this vary over the year? If so, estimate the number of each of each during a year:

____

____

☐ Do the animals get fodder from another source than from the farm? ________________

☐ If yes: how much fodder is bought in a week/ year? If local unit is used, the interviewer will weigh the unit on site:

____

☐ How many weeks are fodder bought during a year? _____________________________

	A full-grown animal	A lactating animal	An animal in-calf	A baby animal
What kind of fodder is given to each? (e.g grass, crop residue, concentrates etc.)				
How many days are the animals given fodder during a year?				
How much of each fodder is given to the following in a day?				

Manure collection and management

☐ Do you add something to the manure such as ash or straw etc.? In case of yes, what?

☐ How many units' fresh manure collected and stored annually?

☐ How much manure is used on the farm (state if it is fresh or ready-to-use)?

☐ Do you sell manure? If so; how many units in a year and do you sell fresh or after storing? If local unit is used, the unit need to weight and stated.

☐ Do you buy manure? If so; how many units in a year? If local unit is used, the unit need to weight and stated if possible.

☐ How do you handle/manage the manure?

First storage

- What type of floor is used while collecting/storing the manure?
- Is the floor sloping to enhance feces and & urine collection?
- Is there a gutter that leads to the manure storage or are fluids lost? If yes, where are fluids led?
- Does rain enter the floor creating extra runoff?
- Is the manure stored under a roof or in other way sealed storage?
- Is the manure stirred/shuffled during the storage time?

In case of second storage

- What type of floor is used while storing the manure?
- Is there a gutter that leads to the manure storage or are fluids lost? If yes, where are fluids led?
- Does rain enter the floor creating extra runoff?
- Is the manure stored under a roof or in other way sealed storage?

____

- Is the manure stirred/shuffled during the storage time?

____

☐ Sketch a picture of the storage. Describe its parts, design, and material

Additional nutrient sources

☐ How many persons are there in the household

- Adults __________________
- Children 0-8 yrs_____________
- Children 9-16 yrs____________

☐ How much food is bought in the household (each day or week) and what kind of food is it roughly?

____

____

____

☐ What is the fate of the kitchen waste?

____

____

☐ Do you keep a compost on the farm? If yes: how much compost is added in a day?

____

☐ What is the fate of the content of composting toilet? (E.g burned, spread on fields, treechamber well, buried etc)

____

____

☐ Does the privy have a closed system, a communal system or does nutrient loss from the privy occur on the farm?

____

____

☐ Where is the privy placed in relation to irrigation water sources, vegetation, and fields?

____

____

____

____

☐ Do you use night soil?

- If so, where is it used?

  ____

  ____

- How many units do you use in a year?

  ____

  ____

- Is it mixed with something, in that case how many units of e.g chalk, soil, sawdust, moss or straw is added in a year?

  ____

  ____

- Is it treated before (e.g by composting)

  ____

  ____

  ____

☐ Sketch a picture of the privy. Describe its parts, design, and material

Fishpond

____

☐ Do you have a fishpond on the farm? ____

☐ Do you produce fish in the pond? ____

☐ If so: how much do you sell and how much is consumed on the farm?

____

____

☐ Do you use the pond for irrigating fields, in that case which fields?

☐ Approximately how much water is used for the irrigation in a year?

☐ Do you have other uses for the pond? If yes: describe them. -

Farm ID:														
Type of animal:		Does not apply on farm	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	Animal birth													
	Purchase of animal													
	Purchase of animal feed													
	Fed in barn													
	Fed while tethered													
	Grazing freely													
	Manure moved from barn to storage 1													
	(Manure moved from barn to storage 2)													
	Manure transfered to fields													
	Animal sales													
	Product sales													

Farm ID:														
Type of animal:		Does not apply on farm	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
	Animal birth													
	Purchase of animal													
	Purchase of animal feed													
	Fed in barn													
	Fed while tethered													
	Grazing freely													
	Manure moved from barn to storage 1													
	(Manure moved from barn to storage 2)													
	Manure transfered to fields													
	Animal sales													
	Product sales													

Farm ID:

Field nr:

		Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Crop: ____________	Land preparation												
	Planting												
	Nutrient input												
	Irrigation												
	Harvest												
	Remove/ move of crop residue												
Crop: ____________	Land preparation												
	Planting												
	Nutrient input												
	Irrigation												
	Harvest												
	Remove/ move of crop residue												
Crop: ____________	Land preparation												
	Planting												
	Nutrient input												
	Irrigation												
	Harvest												
	Remove/ move of crop residue												
Crop: ____________	Land preparation												
	Planting												
	Nutrient input												
	Irrigation												
	Harvest												
	Remove/ move of crop residue												
Crop: ____________	Land preparation												
	Planting												
	Nutrient input												
	Irrigation												
	Harvest												
	Remove/ move of crop residue												

B NPK concentrations used in the report.

Table 19: NPK concentration of fodder. The NPK concentration has been estimated by using the same fodder as in the remaining farms with the equivalent type of animal. The potassium value in the pig fodder was estimated in Table 25. The K - concentration in duck fodder and chicken fodder was estimated in Table 26 and Table 24. For ducks, the values for duckling starter 3 weeks and older were used, and for chicken and pigs, the average value was used. For Goat fodder values for the grass were used as it was not clear from the interview if they received bought fodder or just grass

	Type of fodder	**N-concentration %**	**P-concentration %**	**K-concentration %**
1	Pig fodder (1 - 3 month)	8.11	1 - 2	0.63
1	Pig fodder (> 3 month)	> 3.77	0.5 - 1	0.63
1 [a]	Chicken fodder	3.96	0,75	0.73
2 [a]	Pig fodder	3.4 - 9.06	0.5 - 2	0
3	Chicken fodder (1 - 14 days)	3.96	0.5 - 1	0.73
3	Pig fodder (15 kg - 30 kg)	3.4	0.6 - 1.2	0.63
5	Chicken fodder	3.58	0.7 - 1.2	0.73
5	Goat fodder*	1.05	0.13	2.23
6 [a]	Pig fodder	4.06	0.85	0.63
7	Chicken fodder AF plus 3010 (1 - 21 days old)	3.96	0.5 - 1	0.73
7 [a]	Pig fodder	4.06	0.85	0.63
8	Pig fodder	2.64	0.5 - 1	0.63
9	Chicken fodder AF plus 3010 (used for the ducks?) (1 - 21 days old)	3.96	0.5 - 1	0.73
9	Duck fodder F61 (> 29 days)	3.30	0.5 - 1	0.78
10	Pig fodder	9.06	1 - 2	0.63

[a]Information from the specific farm could not be conducted.

Table 20: N, P, and K concentration of fertilizers

NPK-ratio	**N-conc. [%]**	**P-conc. [%]**	**K-conc. [%]**
6:9:3	6	3.92	2.49
8:9:3	8	3.92	2.49
13:5:9	13	2.18	7.47
18:10:8	18	4.36	6.64
18:3:22	18	1.31	18.26
13:13:13	13	5.67	10.79
14-7	14	0	5.81
5:10:3	5	4.36	2.49
20:2:20	20	0.87	16.6
16:12:8	16	5.23	6.64
20:2:20	20	0.87	16.6
16:10:14	16	4.36	11.62
5:12:3	5	5.23	2.49
N fertilizer	46.3	0	0
P fertilizer	0	8.72	0
K fertilizer	0	0	49,8

Table 21: NPK concentration of some grains, nuts, and fruits

	N-concentration [%]	**P-concentration [%]**	**K-concentration [%]**
Macadamia nuts [k]	1.43 - 1.6	0.21 - 0.26	0.37 - 0.44
Macadamia husk	1.78 [a]	0.057 [a]	2.79 [a]
Rice husk	0.48 - 0.63 [b d]	0.50 - 0.61 [b d]	0.78 - 1.5 [b d]
Rice straw	0.6 - 0.65 [e g]	0.07- 0.54 [e f g]	1.4 - 2.4 [e g f]
Rice grain (whole grain)	1.1 - 1.32 [g j]	0.2 - 0.24 [g j]	0.19 - 0.29 [g j]
Rice grain, polished [j]	1.28	0.081	0.035
Maize grain [h]	1.3	0.194	0.43
Maize residues [h]	0.50	0.073	1.32
Grass [h]	1.05	0.13	2.23
Mango [j]	0.094 - 0.2	0.009 - 0.022	0.13 - 0.19
Dragonfruit	0.32 [l]	0.015 [l]	0.15829 [i]
Pear [j]	0.11	0.010 - 0.012	0.062 - 0.13
Longan [j]	0.19	0.023	0.22
Plum [j]	0.15	0.039	-
Pomelo [j]	0.11	0.022	0.31
Sugarcane [in kg/ m^2] [c]	0.0122 - 0.0154	0.0017 - 0.0023	0.02 - 0.0276
Sugarcane tops (residue) [p]	0,091	0,0085	0.24
Black bean (dried) [j]	4	0.362	0.004
Soy bean [j]	6	0.38 - 0.53	0.4 - 0.99
Banana shoot and young stem [j]	0.13	0.034	-
Lemon [j]	0.11 - 0.13	0.006 - 0.017	0.18 - 0.46
Passion fruit peel [q]	0.13	-	0.28
Coffee bean	0.09 - 0.52 [m]	0.0159 - 0.125 [m]	1.99 [n]
Vegetables [j]	0.41	0.044	0.3
Meat (beef and pork incl intestines, bones and fat) [j]	2.67 - 6.77	0.06 - 0.24	0.19 - 0.37
Freshwater fish *Puntius Stigma* [o]	4.02 - 4.35	0.24 - 0.25	0.66 - 0.72

The values in Table 21 were taken from (Maselesele et al., 2021)[a], (Abbas, 2012) [b], (Moore & Botha, 2014) [c], (Thiyageshwari et al., 2018)[d], (Ponnanaperuma, 1984) [e], (Doyle et al., n.d.) [f], (Fairhurst et al., 2007) [g], *(Hung,2022 PhD student, SLU, ICRAF Hanoi, Vietnam)* [h], (Luu et al., 2021) [i],(ASEAN, 2014)[j], (Richards et al., 2020) [k],(Ramírez-Rodríguez et al., 2019) [l], (Hifnalisa et al., 2022) [m], (Adler et al., 2019) [n], (Musa, 2009) [o], (Golden & Ricaud, 1963) [p], (Corrêa et al., 2016) [q] Notes: -: No values found. The conversion factor from protein to N-concentration taken from (ASEAN, 2014) was used for dragonfruit as well. The value for vegeatbles is an avarage value of spinach, cabbage, leek, onion, parsley and coriander as they give a good astimation of an avarage value. The choise of Puntius Stigma is based on that amongst the more common fish specieas in the area, the carp is the most frequent one.

Table 22: NPK concentration in compost. The Chicken manure is based on an average value on sample 6,7 and 10. These samples were chosen due to similar moisture content. The value for pig manure and cow manure is taken from sample 7 and 10. Remaining values are given from the analysis of NPK concentration in the SFRI lab in Hanoi.

	Type of compost	**Stirring**	**Composting time**	**N conc. % WS**	**P conc. % WS**	**K conc. % WS**	**moisture %**
1 [a]	Buffalo (and pig) manure (96 %) with rice straw (2 %), rice husk (1.4 %), probiotics and sugar	Every 20 days	3 month	1.71	0.31	0.7	
2	Cow (75 %) and pig (25 %) manure	None	3 month	0.42	0.47	0.18	76.55
3	Cow (51%) and pig (15 %) with macadamia peel (33 %), probiotics and sugar	Every 15 days	2 month	0.36	0.16	0.013	78.31
8	Cow (50 %) and buffalo (50 %) with probiotics	None	2 month	0.86	0.35	0.88	51.74
10	Cow manure (bought)	-	-	0.57	0.24	0.94	54.69
4 [a]	Cow manure	None	2 month	0.57	0.37	0.94	-
7 [a]	Cow manure (bought)	-	-	0.57	0.37	0.94	-
5	Goat manure	None	3 weeks	0.97	0.53	1.01	26.85
7	Pig manure	1 time at start	2 month	1.77	0.78	0.67	53.86
8 [a]	Pig manure with probiotics	None	2 month	1.77	0.78	0.67	-
10 [a]	Pig manure	None	2 - 3 month	1.77	0.78	0.67	-
4	Chicken manure	None	2 month	0.58	0.37	0.39	71.16
6	Chicken manure	None	None	1.98	1.37	1.45	14.44
7	Chicken manure	1 time	2 month	2.28	1.08	1.27	15.14
5 [a]	Chicken manure	None	3 weeks	2.27	1.083	1.113	-
9 [a]	Chicken manure	None	None	2.27	1.083	1.113	-
10	Chicken manure	1 time	2 - 3 month	2.54	0.8	0.62	13.44
9	Duck manure (90 %) with rice husk (10 %)	1 time at start	1 month	0.74	1.29	0.87	38.83

Table 23: Potassium concentration in animal fodder. Taken from (Perry, 1984) and (Seerley, 1991)

	Average % of potassium	% of DM
Meat and bone meal	1,02	93
Fish meal	0,76	92 - 95
Yellow corn	0,30	89
Soybean meal	1,95	89 - 90
Alfa alfa meal	2,21	92
Wheat, hard winter	0.45	87
Oats	0.38	89
Wheat midds	0.99	88

Table 24: The potassium content in typical Poultry fodder. Calculated using literature values taken from (Perry, 1984). The average potassium concentration in poutlry fodder is 0.73 %.

	Poultry 0 - 5 weeks	**Poultry 5 - 10 weeks**	**Broiler starter 0 - 4 weeks**	**Broiler finisher 4 - 8 weeks**	**Roaster finisher more than 8 weeks**
Yellow corn [lb]	1292,5	1354	1206	1281	1503,5
Alfa alfa [lb]	20	100	0	0	0
Soybean meal [lb]	521	475	481	389	210
Meat and bone meal [lb]	100	0	141	123	143
Fish meal [lb]	30	0	50	50	0
Total weight [lb]	1963.5	1929	1878	1843	1856,5
Total % of potassium	*0,80*	*0,80*	*0,79*	*0,71*	*0,54*

Table 25: The content in typical corn-based swine fodder. the table shows six different swine fodders and the main content given in [lb]. The average value of potassium in corn-based swine fodder is according to the table 0.63 %. Calculated using literature values taken from (Perry, 1984) and (Seerley, 1991)

	1	**2**	**3**	**4**	**5**	**6**
Yellow corn [lb]	1565	795	1370	1230	1570	1615
Wheat, hard winter [lb]	-	800	-	-	-	-
Oats [lb]	-	-	200	-	-	-
Wheat midds [lb]	-	-	-	400	-	-
Soybean meal [lb]	380	350	375	320	330	325
Meat and bone meal [lb]	-	-	-	-	65	-
Total weight [lb]	1945	1945	1945	1950	1965	1940
Total % of potassium	*0,62*	*0.66*	*0,63*	*0,71*	*0.60*	*0,58*

Table 26: The content in Duck fodder. The resource is taken from white paper of master list of poultry mixes from Mt. Hope Ag Center, Mt. Hope, Ohio and (Ibáñez et al., 2020). K is the concentration of potassium.

	Duckling starter 1 - 2 weeks	**Duckling starter 3 weeks and older**
Maize [lb]	1242	1482
Soybean [lb]	680	450
Sum [lb]	1922	1932
Maize [Prop]	0,646202	0,767081
Soybean [Prop]	0,353798	0,232919
K conc in Maize	0,0036	0,0036
K conc in Soybean	0,021675	0,021675
% of K in mixture	*0,995*	*0,781*

Table 27: NPK concentration in chicken and duck. the table shows an estimation of the nutrient concentration in the carcass of a Muscovy duck and broiler chicken. The values of nutrient concentration in a duck is estimated using the nutrient value of chicken meat and bone meal. Chicken meat is used to estimate the nutrient value in the skin. Values for Muscovy duck were taken from ((Kleczek et al., 2007)) and for chicken from (ASEAN, 2014), (Hayse & Marion, 1973), (USDA, 2012), and (Hafid et al., 2021).

	% of Duck carcass	N	P	K
Meat	51.5	5.13 [%]	0.24 [%]	0.34 [%]
Bone	26,2	2.38 [%]	12.58 [%]	0.09 [%]
Skin	13,3	5.13 [%]	0.24 [%]	0.34 [%]
nutrients in duck carcass with average weight of 4540,1 g		179 [g]	157 [g]	11 [g]
% of nutrient in whole duck		3.9	3.5	0.24
	% of chicken carcass	N	P	K
Meat	59.88	5.13 [%]	0.24 [%]	0.34 [%]
Bone	23.49	2.38 [%]	12.58 [%]	0.09 [%]
Skin	14.49	5.13 [%]	0.24 [%]	0.34 [%]
nutrients in chicken carcass with average weight of 1925 g		84 [g]	60 [g]	5 [g]
% of nutrient in whole chicken		4.4	3.1	0.27

Table 28: The values show the % of N, P and K in some animals on the farm. values for pigs are gathered from (Millet et al., 2018), and for cows from (Council, 2003; Honig et al., 2022)

	N [% whole animal]	P [% of whole animal]	K [% of whole animal]
Piglet 8-8,5 kg	2,5	0.74	1.1
Pig (100-107 kg)	2,8	0.67	1.3
Cow (100-800 kg bull)	2.3	0.27	2.02

Table 29: Typical NPK concentration of manure.The values show the % of fresh organic material.

	N [% of fresh material]	P [% of fresh material]	K [% of fresh material]
Pig feaces	0.5	0.2	0.4
Cattle feaces	0.3	0.1	0.1
Fresh cattle manure	0.4 - 0.6	0.1 - 0.2	0.4 - 0.6
Composted cattle manure	1.5	1.2	2.1
Pig manure	0.7 - 1.0	0.2 - 0.3	0.5 - 0.7
Poultry manure	1.4 - 1.6	0.5 - 0.8	0.7 - 0.8
Buffalo compost [5]	1.76	0.44	0.95
Buffalo dung	1.23 [2]	0.55	0.69
Duck manure [2]	2.15	1.13	1.15

in Table 29, values were taken from (Fairhurst et al., 2007) and (Jouquet et al., 2011) [1], (FAO, 1991) [2], (Lee et al., 2012) [3], (Irshad et al., 2013)[4]. In cases where P and K was stated as compounds, the conversion factor from (Fairhurst et al., 2007) was used.

C Calculation example for field 3 in farm 3

In field three to six the fields have 25 grass rows, each 50 m long, as seen in Appendix 50. The total of all four fields have an area of 9200 m. The grass strips are assumed to be approximately 1 m wide.
(50 m* 25 m) / 9200 m^2 = 0.136 0.136 * 2500 m^2 = 340 m^2 grass area.
The Mango has a crop distance of 5 m, as seen in Appendix 50. It is 120 trees in the field. Using the assumption that it has a radius of 3 m gives:
120 * 3 m * 5 m = 1800 m^2 area for the Mango trees.
2 500 m^2 - 1800 m^2 - 340 m^2 = 360 m^2
The area of the maize is approximately 360 m^2.

This calculation is done on all the fields, and the sum of the maize area is calculated and compared to the amount of seeds to check the accuracy of field area estimation.

The total area of maize was calculated to 2490 m^2 for field three, four, five and six. The farmer reported 10 kg of seeds this year as seen in Appendix 50. With an approximation of 0.8 kg harvest per m^2 this would give a harvest of 1875 kg. The farm reported harvesting 1500 kg. Given the 10 kg of used seeds, this would represent an area of 5000 m^2. Given the big difference in reported use of seeds and harvest, it is reasonable to assume that the area is correct.
Nutrient inflow and outflow stated in Table47 is calculated using the values for the total input, and the harvest yield in Table45 and the removed crop residue in Table 46. The input value was multiplied with amount of trees, m^2 field or m of grass in each field. This value was multiplied with the N, P and K values of each fruit, nut and/ or crop/grain. These values were conducted from literature values given in Table 21. This calculation applies to all farm gate balances.

D Information to farm 1

Table 30: General household information for farm 1

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
2	0	0	240 kg rice and 180 kg meat	Organic waste is burned together with the plastic waste. The ash is added to the vegetables in the home garden	Closed system.

Table 31: Crop/ fruit information for field 1. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree, m^2 or as given in Table. Notes: The nutrient concentration of the lifestock water will be estimated to be the same as the average of pig feaces given in Table 29 found in the Appendix, with the estimation that 1 l has a weight of approximately 1 kg. Dragonfruit is grown around pillars, with four plants around each pillar.

	1:st input	**2:nd input**	**3:d input, (4:th input)**	**Total input**	**Harvest 2022**	**Harvest 2021**
Plum	1 kg manure from farm + 0.3 kg 8:9:3	0.3 kg 13:5:9		1 kg manure + 0.3 kg 8:9:3 + 0.3 kg 13:5:9	2-3 kg	30-40 kg
Mango	1 kg manure from farm + 0.3 kg 8:9:3	0.3 kg 13:5:9		+ 1 kg manure + 0.3 kg 8:9:3 + 0.3 kg 13:5:9	2-3 kg	15-20 kg
Longan	2 kg manure + 1,5 kg 8:9:3	2 kg 13:5:9	2 kg 13:5:9	2 kg manure + 1,5 8:9:3 + 4 kg 13:5:9	5 kg	30 kg
Dragon fruit (per pillar)	0.1 kg 8:9:3 + 6,67 l livestock water	0.1 kg 8:9:3 + 6,67 l livestock water	0.1 kg 8:9:3 + 6,67 l livestock water, (0.1 kg 8:9:3 + 6,67 l livestock water)	0.4 kg 8:9:3 + 26.68 l livestock water	4 kg	1.2 kg (due to young plants)
Guinea grass	0.15 kg 8:9:3 + 0.025 kg Nitrogen rich fertilizer	0.15 kg 8:9:3 + 0.025 kg Nitrogen rich fertilizer		0.3 kg 8:9:3 + 0.050 kg Nitrogen rich fertilizer	95 kg / day	-
Maize	0.0583 kg 8:9:3	0.029 kg Nitrogen rich fertilizer		0.0583 kg 8:9:3 + 0.029 kg 13:5:9	Field 1: 1.13 kg, Field 3: 0.75 kg, Field 4: 1.13 kg, Field 6: 0.39 kg	-
Rice	0.0267 kg Nitrogen rich fertilizer + 0.0933 kg 8:9:3	0.033 kg 13:5:9		0.0267 kg nitrogen 46% + 0.093 kg 8:9:3 + 0.033 kg 13:5:9	1.5 kg	1.5 kg
Soy bean	0.015 kg 8:9:3			0.015 kg 8:9:3	0.07 kg	0.07 kg
Vegetables	133,33 kg manure + 3 kg Nitrogen rich fertilizer + 15 kg 8:9:3	133,33 kg manure + 3 kg Nitrogen rich fertilizer + 15 kg 8:9:3	133,33 kg mff + 3 kg Nitrogen rich fertilizer + 15 kg 8:9:3	400 kg mff + 9 kg 8:9:3 for the entire field	247.5 kg for the entire field	247.5 kg for the entire field / year

Table 32: Crop residue on farm 1

Plum	Mango	Longan	Dragon fruit	Maize	Rice	Soy bean
Big branches are burned for cooking	Big branches are burned for cooking	Big branches are burned for cooking	Left on the field	Left on the field	Rice straw used in the manure	Left on the field

Table 33: Nutrient balance Field: 1

Field number	1	2	3	4	5	6	7
Inflow							
N [kg]	11.01	5.25	146.78	11.56	14.8	53.76	7.6
P [kg]	3.66	2.19	40.82	4.81	3.27	14.34	2.11
K [kg]	4.45	3.70	39.5	4.79	3.59	13.59	4.14
Outflow							
N [kg]	15.1	1.63	223,46	22.7	10.03	128.48	1.01
P [kg]	2.25	0.08	28.88	3.01	3.04	15.98	0.11
K [kg]	5.04	0.81	389.76	6.42	12.84	266.83	0.74
Balance							
N [kg]	-4.09	2.78	-76.68	-11.11	4.766	-74.72	6.59
P [kg]	1.4	1.69	11.93	1.8	0.23	-1.64	2.00
K [kg]	-0.58	1.62	-350.22	-1.62	-9.25	-252.59	3.4

Table 34: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	**Buffalo**	**Pig**	**Chicken**
Feeding place	Tethered by a tree by farm house	In the pen	Free grazing
Amount and type of feed for adult animal	19 kg guinea grass	2 kg maize	0.02 kg rice
Amount and type of feed for baby animal	19 kg guinea grass	0.43 kg fodder	0.006 kg fodder
Amount of collected	10 kg from adult buffalo + 1 kg from baby buffalo	2.67 kg	0 kg

Table 35: the table shows the number adult and baby animals for each kind of animal for each month during the year. 20 baby pigs were born at the farm, and sold at the age of one month. One baby buffalo was born, and sold after 8 month.

	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Adult chicken	38	36	64	62	60	58	56	54	52	50	48	46
Baby chicken	30	30	30	0	0	0	0	0	0	0	0	0
Adult buffalo	4	4	4	4	4	4	4	4	4	4	4	4
Baby buffalo	1	1	1	1	1	1	1	1	1	1	0	0
Adult Pig	3	3	3	3	3	3	3	3	3	3	2	2
Baby pig	0	0	0	0	0	0	0	20	0	0	0	0

Table 36: 1

Total amount of maize seeds	1.5 kg in field 4.
Irrigation	Water taken from the pond located on a lower elevation next to the house and barn
Crop distance	In field 1: 5 m between trees and 10 m between the rows. Field 3: 3 m between trees and 5 m between rows. Field 6: 3 m between trees and 6 m between rows. Between maize rows and trees it is 0.7 m. The grass rows are estimated to be 4 m wide from field visit, and grown at the same row as the trees.
Fishpond	Yes, without fish

E Information to farm 2

Table 37: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
3	1	1	240 kg rice, 288 kg meat, 144 kg fish	Plastic is burned, no use of the ash and organic waste is thrown in a separate pile	Closed system

*Table 38: Crop/ fruit information for field 2. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree or as given in Table. * 4 kg fresh nuts (Macadamias, n.d.)*

	1:st input	**2:nd input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Mango	25 kg manure + 0.5 kg Nitrogen rich fertilizer + 0.5 kg Phosphorous rich fertilizer	0.5 kg Phosphorous rich fertilizer + 0.5 kg 14-7	25 kg manure + 0.5 kg Nitrogen rich fertilizer + 1 kg Phosphorous rich fertilizer + 0.5 kg Potassium rich fertilizer	5 kg	20 kg
Longan	25 kg manure + 1 kg Nitrogen rich fertilizer + 1 kg Phosphorous rich fertilizer	1.5 kg 14-7 + 1/15 bottle micronutrients	25 kg manure + 1 kg Nitrogen rich fertilizer + 1 kg Phosphorous rich fertilizer + 1.5 kg Potassium rich fertilizer + 1/15 bottle micronutrients	66,7 kg	113,3 kg
Macadamia	30 kg manure	1 kg 13:13:13	30 kg manure + 1 kg 13:13:13	3 kg dry nuts* + 6 kg fresh nuts (only from the 7 years old trees)	-
Elephant grass	0.02 kg Nitrogen rich fertilizer	0.02 kg Nitrogen rich fertilizer	0.04 kg Nitrogen rich fertilizer	75.2 kg / day	75.2 kg /day
Maize	0.083 kg 6:9:3	0.02 kg 46 %	0.083 kg 6:9:3 + 0.02 kg 46 %	0.71 kg	-
Sugarcane	0.03 kg 18:10:8	0.03 18:3:22	0.03 kg 18:10:8 + 0.03 18:3:22	7.27 kg	9.09 kg
Vegetables	(? 0.4 kg manure + 0.005 kg NPK (any kind)		(? 0.4 kg manure + 0.005 kg NPK (any kind)	(? kg)	(?kg)

Table 39: Crop residue

Mango	Longan	Macadamia	Maize	Sugarcane
Small branches left on the field. Big branches are burned for cooking	Small branches left on the field. Big branches are burned for cooking	Small branches left on the field. Big branches are burned for cooking	1000 kg put around the small macadamia trees on the fields. The rest is left on the field	20 000 kg used as fodder. 30 000 kg burned

Table 40: Field Balance

Field number	1	2	3	4	5
Inflow					
N [kg]	42.97	12.8	41.122	9.2	237.6
P [kg]	24.58	9.14	9.44	0	49.24
K [kg]	41.7	8.1	5.99	0	164.34
Outflow					
N [kg]	2.64	7.53	26.77	288.2	301.96
P [kg]	0.31	7.53	26.77	288.2	301.95
K [kg]	3.0	0.79	8.85	612.1	523.6
Balance					
N [kg]	40.33	5.28	14.36	-279.0	-64.35
P [kg]	24.27	8.34	5.44	-35.68	5.24
K [kg]	38.7	7.31	-2.86	-612.1	-359.26

Table 41: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	**Cow**	**Pig**	**Chicken**
Feeding place	In the barn	In the barn	Grazing freely
Amount and type of feed for adult animal	18.8 kg Elephant grass	0.033 kg fodder + 1 kg maize	0.02 kg maize
Amount and type of feed for baby animal	-	-	0.02 kg maize
Amount of collected manure	7.5 kg	2.5 kg	0 kg

Table 42: Alteration of the number of animals. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult cow	4	4	4	4	4	4	4	4	4	4	4	4
Baby cow	0	0	0	0	0	0	0	0	0	0	0	0
Adult pig	1	1	1	1	1	1	1	1	1	1	1	1
Baby pig	0	0	0	0	0	0	0	0	0	0	0	0
Adult chicken 26	26	26	25	24	23	22	21	20	19	18	17	16
Baby chicken	0	0	0	0	0	0	0	10	10	10	0	0

Table 43: 2

Total amount of maize seeds	6 kg
Fishpond	No
Irrigation	Water taken from the communal pond when its no rain. Jan - March the home garden was irrigated 4h / day.
Crop distance	5 m between rows and 5 m between plants for macadamia. 3.5 m between fruit trees.
Grass as erosion control	The grass is grown vertically along the slope, and does not work as erosion control

F Information to farm 3

Table 44: General household information for farm 3

Number of Adults >16 years old	Number of children 9-16 years old	Number of children 0-8 years old	Amount of bought during a year	Fate of the kitchen waste	System and location of privy and its waste
4	0	2	480 kg rice, 120 kg meat and 360 kg vegetables	Garbage collector picks up plastic and organic waste	Closed system

Table 45: Crop/ fruit information for field on farm 3. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree or as given in Table.

	1:st input	**2:nd input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Plum	20 kg manure + 2 kg 13:5:9	2 kg 13:5:9	20 kg manure + 4 kg 13:5:9	26 kg	26 kg
Mango	20 kg manure + 2 kg 13:5:9	2 kg 13:5:9	20 kg manure + 4 kg 13:5:9	5 kg	12.5 kg
Longan	20 kg manure + 2 kg 13:5:9	2 kg 13:5:9	20 kg manure + 4 kg 13:5:9	4 kg	13 kg
Macadamia	Field 1: 30 kg manure + 1.06 kg 13:5:9, Field 6: 10 kg manure + 0.3 kg 13:5:9	Field 1: 30 kg manure + 1.06 kg 13:5:9, Field 6: 10 kg manure + 0.3 kg 13:5:9	Field 1: 60 kg manure + 2.12 kg 13:5:9, Field 6: 20 kg manure + 0.6 kg 13:5:9 per tree	Field 1: 3.7 kg (no harvest yet from field 6)	Field 1: 3.7 kg
Guinea grass	No input	No input	No input	30-40 kg / day	-
Maize	0.08 kg 13:5:9	0.02 kg Nitrogen rich fertilizer	0.08 kg 13:5:9 + 0.02 kg Nitrogen rich fertilizer	0.6 kg	-
Black bean	No input	No input	No input	0.175 kg	-
Vegetables	0.04 kg 13:5:9	-	0.04 kg 13:5:9	120 kg / year for the entire field	-

Table 46: Crop residue

Plum	**Mango**	**Longan**	**Macadamia**	**Maize**	**Black bean**
Leaves are left on the field and branches are brought to the house for cooking	Leaves are left on the field and branches are brought to the house for cooking	Leaves are left on the field and branches are brought to the house for cooking	Leaves are left on the field and branches are brought to the house for cooking. 2500 kg macadamia peel used as fodder.	Left on the field	Left on the field

Table 47: Field Balance

Field number	1	2	3	4	5	6	7
Inflow [kg]							
N	52.11	23.68	78.096	55.96	52.14	29.56	0.26
P	15.075	4.77	14.93	9.9	7.97	7.39	0.044
K	17.61	12.06	38.32	26.01	21.94	9.26	0.15
Outflow [kg]							
N	51.57	38.50	18.13	16.85	23.66	17.25	0.49
P	6.18	4.77	2.3	2.21	3.43	2.21	0.053
K	91.67	81.48	33.48	26.58	30.02	31.59	0.36
Balance [kg]							
N	0.54	-14.82	59.97	39.12	28.48	12.31	-0.23
P	8.89	0.0018	12.63	7.69	4.54	5.18	-0.0092
K	-74.06	-69.42	4.84	-0.57	-8.07	-22.33	-0.21

The amount of feed per day for cows in Table 48 is based on a value given for both cows in total. In this case, the calculation does not consider the first weeks when the cow only drink milk. In the case of pigs, the assumption is that the pigs mainly drink milk the first two month.

Table 48: Animal feed and manure collection

Kind of animal	**Cow**	**Pig**	**Chicken**
Feeding place	In the barn	In the barn	Grazing freely
Amount and type of feed for adult animal	20 kg fodder grass	0.3 kg fodder + 2.5 kg maize (kolla upp igen och jämför med andra gårdar. står olika i anteck-ningarna)	0.02 kg maize + 0.01 kg fodder
Amount and type of feed for baby animal	20 kg fodder grass	milk from the mother	0.02 kg maize + 0.01 kg fodder
Amount of collected manure	10 kg	3 kg	0 kg

The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Table 49: Alteration of the number of animals on farm 3. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult cow	1	1	1	1	1	1	1	1	1	1	1	1
Baby cow	1	1	1	1	1	1	1	1	0	1	1	1
Adult pig	2	2	2	2	2	2	2	2	2	2	2	2
Baby pig	0	0	0	0	0	8	8	0	0	0	0	0
Adult chicken	79	77	64	51	39	27	25	22	20	17	100	100
Baby chicken	0	0	0	0	0	0	80	80	80	80	0	0

Table 50: 3

Total amount of maize seeds	10 kg
Fishpond	No
Grass strips	In field 3-6 there are 25 rows, each 50 m long. In field 1-2 the rows are 25 m long.
Crop distance	1 m between grass rows and trees. 5 m between trees and 7 m between rows for all fruit trees. In field 1: 5 m between macadamia plant and 7 m between rows. In field 6: 4 m between both macadamia trees and rows.

G Information to farm 4

Table 51: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
2	1	1	384 kg rice and 96 kg fish	Plastic waste is collected by the garbage collector, and the organic waste is put around the trees in around the house	One with closed system and one additional privy with open system that is rarely used.

Table 52: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree or as given in Table.

	1:st input	**2:nd input**	**3:d input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Pomelo	7 kg manure	1 kg 13:5:9	0.5 kg potassium	7 kg manure + 1kg 13:5:9 + 0.5 kg potassium	Not applicable. Harvest in Dec.	25 kg
Mango	7 kg manure	1 kg 13:5:9		7 kg manure + 1 kg 13:5:9	2 kg	8 kg
Longan	7 kg manure	1 kg 13:5:9		7 kg manure + 1 kg 13:5:9	3.3 kg	22.2 kg
Guinea grass	0.067 kg 18:10:8	0.067 kg 18:3:22		0.067 kg 18:10:8 + 0.067 kg 18:3:22	2.73 kg/ day kg	- kg
Maize	0.06 kg 14:7	0.028 Nitrogen rich fertilizer		0.6 kg	0.6 kg	-
Sugarcane	Field 1: 0.05 kg 18:10:8, Field 2: 0.04 kg 18:10:8	Field 1:0.05 kg 18:3:22, Field 2: 0.04 kg 18:3:22		Field 1: 0.05 kg 18:10:8 + 0.04 kg 18:3:22, Field 2: 0.05 kg 18:10:8 + 0.04 kg 18:3:22	Field 1: 6.67 kg, Field 2: 7.67 kg	-
Vegetables	3 kg chicken manure			-	-	-

Table 53: Crop residue

Pomelo	Mango	Longan	Maize	Sugarcane
Left in the field	Left in the field	Left on the field	Left on the field	20 - 30 kg collected during Dec - May and given to two cows

Table 54: Field Balance

Field number	1	2	3	4
Inflow [kg]				
N	27.08	48.6	53.2	5.78
P	5.83	10.26	0	1.62
K	18.09	31.87	8.72	7.27
Outflow [kg]				
N	65.95	41.18	19.5	0.36
P	8.55	6.	2.91	0.064
K	133.07	71.4	6.45	0.87
Balance [kg]				
N	-38.87	9.51	33.7	5.42
P	-2.73	4.46	-2.91	1.56
K	-114.98	-34.02	2.27	6.4

Table 55: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	**Cow**	Duck	**Chicken**
Feeding place	Mainly fed in the barn. Occasionally free grazing in field accompanied by the farmer	Free grazing	Free grazing
Amount and type of feed for adult animal	5.64 kg fodder grass + 6.27 kg sugarcane residue + 2.5 kg passion fruit peel + 2.5 kg banana tree trunk	0.044 kg maize + 0.25 kg banana tree trunk	0.044 kg maize + 0.25 kg banana tree trunk
Amount and type of feed for baby animal	-	No baby ducks	-
Amount of collected manure	10 kg	0 kg	0.008 kg

Table 56: Alteration of the number of animals on farm 4. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Adult cow	1	1	1	1	1	1	1	1	1	1	1	1
Baby cow	1	1	1	1	1	1	1	1	1	1	1	1
Adult Duck	7	7	7	6	6	6	5	5	4	4	4	3
Baby duck	0	0	0	0	0	0	0	0	0	0	0	0
Adult chicken	24	22	20	18	36	34	32	30	28	26	24	22
Baby chicken	20	20	20	20	0	0	0	0	0	0	0	0

Table 57: 4

Total amount of maize seeds	5 kg
Crop distance	In the home garden the crop distance is 2.5 - 3 m and in the field 5 - 7m.
Fishpond	No
Grass strips	1 row with 10 m, second row with 15 m and third row with 20 m. Harvest 200 kg/ month between june-okt
Crop distance	-

H Information to farm 5

Table 58: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
2	1	1	300 kg rice, 60 kg meat, 24 kg fish	Garbage collector takes all waste	closed system

Table 59: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree or as given in Table.

	1:st input	**2:nd input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Mango	Field 1: 20 kg goat manure, Field 2: 1 kg 13:5:9	Field 2: 1 kg 13:5:9	Field 1: 20 kg goat manure, Field 2: 2 kg 13:5:9	Field 1: 2 kg, Field 2: 4.9 kg	Total of 14 kg
Longan	Field 1: 20 kg goat manure, Field 2: 1 kg 13:5:9	Field 2: 1 kg 13:5:9	Field 1: 20 kg goat manure, Field 2: 2 kg 13:5:9	Field 1: 23 kg, Field 2: 7.35 kg kg	Total of 10 kg
Pomelo	20 kg goat manure		20 kg goat manure	30 kg	30 kg
Guinea grass	0.02 kg Phosphorous rich fertilizer		0.02 kg Phosphorous rich fertilizer	8.6 kg / day	-
Maize	0.055 kg Phosphorous rich fertilizer	0.028 kg Nitrogen rich fertilizer	0.055 kg Phosphorous rich fertilizer + 0.028 kg Nitrogen rich fertilizer	2000 kg	-
Sugarcane	0.04 kg 18:10:8	0.04 kg 18:3:22	0.04 kg 18:10:8 + 0.04 kg 18:3:22	5.6 kg	5.6 kg
Banana	0.09 kg Phosphorous rich fertilizer		0.09 kg Phosphorous rich fertilizer	1 kg / day	-
Vegetables	0.6 kg chicken manure		0.6 kg chicken manure	-	-

Table 60: Crop residue

Pomelo	**Mango**	**Longan**	**Banana**	**Maize**	**Sugarcane**
Big branches used for cooking, and small branches left on the field	Big branches used for cooking, and small branches left on the field	Big branches used for cooking, and small branches left on the field	Banana trunk is given to the animals	Left on the field	12 ton crop residue is harvested and sold in a year

Table 61: Field Balance

Field number	1	2	3	4
Inflow [kg]				
N	24.15	93.1	184.32	0
P	8.65	35.51	38.2	4.32
K	19.18	54.12	127.49	0
Outflow [kg]				
N	1.42	59.45	186.6	0.47
P	0.21	8.02	26.63	0.16
K	2.49	79.17	333.44	0
Balance [kg]				
N	22.73	33.65	-2.28	-0.47
P	8.43	27.49	11.56	4.16
K	16.69	-25.05	-205.95	0

Table 62: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	**Goat**	**Chicken**
Feeding place	Fed in the barn in the morning, and free grazing in the home garden and occasionally in the uphill field	Free grazing
Amount and type of feed for adult animal	0.06 kg fodder + 2.2 kg banana trunk	0.025 kg fodder + 0.025 kg maize + 0.25 kg banana trunk
Amount and type of feed for baby animal	0.06 kg fodder + 2.2 kg banana trunk	0.016 kg maize + 0.01 kg fodder
Amount of collected manure	3.28 kg	0.02 kg

Table 63: Alteration of the number of animals on farm 5. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult chicken	15	13	10	32	30	27	25	22	20	18	35	32
Baby chicken	24	24	24	0	0	30	30	30	30	30	0	0
Adult goat	4	4	4	4	4	4	4	4	4	4	4	4
Baby goat	5	5	5	5	5	5	5	5	5	5	5	5

Table 64: 5

Total amount of maize seeds	4 kg
Fishpond	No
Crop distance	4 m between trees and 6 m between the rows of the fruit trees.
Fodder grass	Grass was sold for 2.5 million dongs. Each batch is 2-3 kg and she sells 30-40 batches 3 times a week continously during three month of the year. . She rarely gives grass to the goat, and only 2-3 kg.

I Information to farm 6

Table 65: General household information

Number of Adults >16 years old	Number of children 9-16 years old	Number of children 0-8 years old	Amount of bought food during a year	Fate of the kitchen waste	System and location of privy and its waste
2	1	1	240 kg rice, 144 kg meat and fish	Burned. Ash not used	closed system

Table 66: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree or as given in Table. Dragonfruit is grown around pillars, with four plants around each pillar.

	1:st input	**2:nd input**	**3:d input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Mango	0.5 kg 5:10:3 + 1 kg 1 kg 13:5:9	1 kg 13:5:9	0.5 kg 5:10:3 + 0.5 kg 13:5:9	1 kg 5:10:3 + 2.5 kg 13:5:9	Field 1 and 6: 22.2 kg, Field 2: No harvest due to bad weather	13.8 in both fields
Longan	1.5 kg 5:10:3 + 2 kg 13:5:9	3 kg 13:5:9		1.5 kg 5:10:3 + 5 kg 13:5:9	Field 1 and 6: 33 kg, Field 2: No harvest due to bad weather	Field 1: 33 kg, Field 2: No harvest due to bad weather
Dragon fruit (per pillar)	0.5 kg 18:3:22	0.3 kg 18:3:22 7 times (every 21:st day)	0.3 kg Nitrogen rich fertilizer	2.6 kg 18:3:22 + 0.3 kg Nitrogen rich fertilizer	20.3 kg	-
Guinea grass	No fertilizer used				1.3 kg / day	-
Maize	Field 2: 0.077 kg 5:10:3, Field 5: 0.07 kg Nitrogen rich fertilizer			Field 2: 0.077 kg 5:10:3 + Field 5: 0.07 kg Nitrogen rich fertilizer	0.81 kg	-
Sugarcane	0.023 kg 18:10:8	0.035 kg 18:3:22	0.016 kg Nitrogen rich fertilizer	0.023 kg 18:10:8 + 0.035 kg 18:3:22 + 0.016 kg Nitrogen rich fertilizer	8.37 kg	-
Vegetables	0.28 kg chicken manure			0.28 kg chicken manure	180 kg / year for the entire field	-

Table 67: Crop residue

Mango	Longan	Dragon fruit	Maize	Sugarcane
Big branches used for cooking and small branches left on the field	Big branches used for cooking and small branches left on the field	Left on the field	Left on the field	8400 kg crop residue is sold

Table 68: Field Balance for farm 6

Field number	1	2	3	4	5	6
Inflow [kg]						
N	38.63	116.16	76.54	33.63	32.2	59.23
P	7.2	32.62	8.98	4.47	0	14.94
K	11.02	65.32	34.05	26.35	0	42.93
Outflow [kg]						
N	8.33	16.85	66.66	14.42	10.53	5.83
P	0.99	2.51	9.	0.68	1.57	0.67
K	14.36	5.57	122.5	7.21	3.48	6.3
Balance [kg]						
N	30.29	99.31	9.88	14.42	21.67	53,4
P	6.2	30.1	-0.34	0.68	-1.57	14.27
K	-3.34	59.75	-88.45	7.21	-3.48	36.63

Table 69: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	Pig	Chicken
Feeding place	In the barn	Grazing freely
Amount and type of feed for adult animal	0.08 kg fodder + 2.5 kg maize	0.033 kg maize
Amount and type of feed for baby animal	-	0.033 kg maize
Amount of collected manure	0 kg	0.027 kg

The pig stable is rinsed with water, and pig feces are not collected. Nutrient losses occur on a farmgate level as the pig manure is not stored and used as a fertilizer on the fields. The stable is located close to the pond, on a higher elevation. The nutrients is likely to be flushed into the pond with excess rainwater, and thus eventually end up on the vegetable garden (field 6), as the water from the pond is used there. However; nutrient losses on the way to the garden will still occur. The nutrient loss per day is estimated to be the average value of pig littering per day using the stated daily values from the farms within the study and the average NPK concentrations. The average value is 3.17 kg manure / day and the average NPK concentration in pig manure is found in Table 29. The loss per year is calculated as: 2 *pigs* * 10 *month* * 30.5 *days per month* * 3.168 kg manure * (N = 0.0085, P = 0.0025, K = 0.006) giving a yearly loss of: 16.52 kg N, 4.86 kg P and 11.66 kg K.

Table 70: Alteration of the number of animals

	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Adult chicken	31	29	27	25	23	21	19	17	15	13	27	29
Baby chicken	0	0	0	0	0	0	15	15	15	15	15	0
Adult Pig	2	2	2	2	2	2	2	2	0	0	2	2
Baby Pig 0	0	0	0	0	0	0	0	0	2	2	0	0

the table shows the number adult and baby animals for each kind of animal for each month during the year.

Table 71: 6

Total amount of maize seeds	3.8 kg in field 2 and 2 kg in field 5. Maize is planted in between the trees and between the tree lines.
Fishpond	No
Crop distance	4 m between trees and 5 m between the rows of the fruit trees.
Fodder grass	5 rows of guinea grass. Maximum lenght is 50 m and minimum length is 15 m. 40 kg of grass is harvested 1 time each month. All harvested grass is given to the neighbor.

J Information to farm 7

Table 72: 7

Total amount of maize seeds	2.7 kg
Fishpond	Yes. Water used to irrigate the home garden. 50 kg of fish per year is used in the household. No fish sold. 13-15 kg of banana leaf, cassava leaf and grass is used as fodder every day in total.
Crop distance	Plum and mango trees have 3 m crop distance and 5 m between rows. For longan it is 5 m between both rows and trees. Dragonfruit has 2,5 m between rows and trees.
Fodder grass	At the beginning, there were 5 rows of grass, each being 200 m long. Now the grass has spread.
Pear	The manure is added with an interval of 1 kg manure one time each month. The trees are only 3 years old, which is why the harvest os so small
Forest trees	Sold as timber. No fertilizers added and no harvest within
Manure	As she sold all of her cows, she has to buy 14 m^3 of cow manure per year (in October). Previously she only had to buy 7 m^3. the last year.

Table 73: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
5	1	1	480 kg rice + 60 kg meat	Plastic waste is collected be the garbage collector, and organic waste is burned. The ash is spread around the trees	Closed system

Table 74: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree, m^2 or as given in Table. Dragonfruit is grown around pillars, with four plants around each pillar.

	1:st input	**2:nd input**	**3:d input, (4:th input)**	**Total input**	**Harvest 2022**	**Harvest 2021**
Plum	3 kg bought cow manure + 1.5 kg 6:9:3			3 kg bought cow manure + 1.5 kg 6:9:3	40 kg	-
Mango	2.5 kg bought cow manure + 2 kg 6:9:3 + Nitrogen rich fertilizer			2.5 kg bought cow manure + 2 kg 6:9:3 + 1 kg Nitrogen rich fertilizer	6.67 kg	13.33 kg
Longan	3 kg bought cow manure + 2 kg 6:9:3 + 1 kg Nitrogen rich fertilizer	1 kg Nitrogen rich fertilizer		3 kg bought cow manure + 2 kg 6:9:3 + 2 kg nitrogen 46	20 kg	60 kg
Dragon fruit (per pillar)	3 kg manure from farm + 1 kg 6:9:3 + 0.5 kg Nitrogen rich fertilizer	1 kg Nitrogen rich fertilizer	1 kg Nitrogen rich fertilizer, (1 kg Nitrogen rich fertilizer)	3 kg manure from farm + 3.5 kg Nitrogen rich fertilizer + 1 kg 6:9:3	16.67 kg	-
Guinea grass	No fertilizer			No fertilizer	11,5 kg / day	11,5 kg / day
Maize	0.15 kg 6:9:3	0.04 kg Nitrogen rich fertilizer		0.15 kg 6:9:3 + 0.04 kg Nitrogen rich fertilizer	0.77 kg	-
Pear	1 kg 6:9:3 + 1 kg manure from farm	1 kg 6:9:3 + 1 kg manure from farm	5 kg manure from farm, (5 kg manure from farm)	2 kg 6:9:3 + 12 kg manure from farm	1.33 kg	-
Pomelo	3 kg bought cow manure + 1.5 kg 6:9:3			3 kg bought cow manure + 1.5 kg 6:9:3	20 kg	-
Lemon	3 kg bought cow manure + 1.5 kg 6:9:3			3 kg bought cow manure + 1.5 kg 6:9:3	5 kg	-
Vegetables	100 kg manure from farm (in total)	100 kg manure from farm (in total)	100 kg manure from farm (in total)	300 kg manure from farm in total	200 kg (in total)	200 kg

Table 75: Crop residue

Plum	Mango	Longan	Dragon fruit	Maize	Pear	Pomelo	Lemon
Left on the field	Left on the field	Left on the field	Left on the field	Left on the field	Left on the field	Left on the field	Left on the field

Table 76: Field Balance for farm 7. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Field number	1	2	3	4	5
Inflow [kg]					
N	117.37	27.2	347.8	35.62	8.4
P	8.03	5.79	46.88	7.64	3.24
K	5.58	4.36	39.81	4.86	3.81
Outflow [kg]					
N	11.16	2.18	47.23	13.01	0.82
P	0.55	0.10	5.89	1.94	0.09
K	5.87	1.11	91.61	4.30	0.6
Balance [kg]					
N	106.21	25.02	300.57	22.61	7.58
P	7.47	5.68	40.98	5.70	3.15
K	-0.29	3.25	-51.81	0.55	3.21

Table 77: Animal feed and manure collection

Kind of animal	**Cow**	**Pig**	**Chicken**
Feeding place	In the barn	In the barn	Free grazing
Amount and type of feed for adult animal	10 kg grass	0.5 kg maize + 0.25 kg fodder + 19.25 kg sweet potato leaf (or banana trunk if sweet potato leaves are not enough)	0.08 kg maize
Amount and type of feed for baby animal	milk	milk	0.027 kg fodder
Amount of collected manure	0 kg (with cows 10 kg)	6 kg	0.017 kg

Table 78: Alteration of the number of animals. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult cow	0	0	0	0	0	0	0	0	0	4	4	4
Baby cow	0	0	0	0	0	0	0	0	0	0	0	0
Adult pig	2	2	2	2	2	2	2	2	2	2	2	2
Baby pig	0	8	0	0	0	0	0	8	0	0	0	0
Adult chicken	140	130	120	110	100	90	80	70	60	50	40	30
Baby chicken	0	0	0	0	0	0	0	0	0	30	30	30

The farm has a fishpond, with a yearly production of 50 kg fish consumed at the farm. Each day the fish is fed 13,5 kg guinea grass.

K Information to farm 8

Table 79: 9

Crop distance	The distance is 5 m between trees and 5 m between the rows for all trees.

Table 80: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
4	0	0	576 kg rice, 144 kg meat and 96 kg vegetables	Burned. 50 kg manure is mixed with ash and the mix is spread around plant after 1 week	Closed system

Table 81: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree, m^2 or as given in Table.

	1:st input	**2:nd input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Plum	10 kg (cow + buffalo) manure + 0.7 kg 13:5:9		10 kg (cow + buffalo) manure + 0.7 kg 13:5:9	35 kg	-
Mango	10 kg (cow + buffalo) manure + 0.7 kg 13:5:9		10 kg (cow + buffalo) manure + 0.7 kg 13:5:9	6.67 kg	-
Longan	10 kg (cow + buffalo) manure + 0.7 kg 13:5:9	0.5 kg 13:5:9	10 kg (cow + buffalo) manure + 1.2 kg 13:5:9	6.67 kg	-
Guinea grass	0.095 kg Nitrogen rich fertilizer		0.095 kg Nitrogen rich fertilizer	120 kg / day (May - Okt)	-
Maize	0.037 kg 6:9:3	0.026 kg Nitrogen rich fertilizer	0.037 kg 6:9:3 + 0.026 kg Nitrogen rich fertilizer	Field 1: 0.4 kg (due to bad soil), Field 3: 0.76 kg	-
Sugarcane	0.037 kg 16:12:8	0.057 kg 20:2:20	0.037 kg 16:12:8 + 0.057 kg 20:2:20	6.67 kg	-
Vegetables	0.33 kg pig or (buffalo + cow) manure + 0.013 kg 6:9:3		0.33 kg pig or (buffalo + cow) manure + 0.013 kg 6:9:3	550 kg per year from the entire field	-

Table 82: Crop residue

Plum	**Mango**	**Longan**	**Maize**	**Sugarcane**
Big branches are burned for cooking and small branches are left on the ground	Big branches are burned for cooking and small branches are left on the ground	Big branches are burned for cooking and small branches are left on the ground	Left on the field	3 ton of top sugarcane residue is harvested

Table 83: Field Balance for farm 8

Field number	1	2	3	4
Inflow [kg]				
N	118.44	25.98	28.36	3.98
P	21.63	3.65	2.9	1.85
K	52.98	17.88	1.84	1.52
Outflow [kg]				
N	248,412	23.32	19.76	2.26
P	31,22	9	2.95	0.24
K	496,82	42.9	6.54	1.66
Balance [kg]				
N	-130	2.66	8.6	1.71
P	-9,59	-5.35	-0.048	1.61
K	-443,83	-25.02	-4.69	-0.14

Table 84: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection. Notes: Rice husk is bought.

Kind of animal	**Buffalo**	**Cow**	**Pig**	**Duck**	**Chicken**
Feeding place	Free grazing in the uphill field during the day and in the barn during night	Free grazing in the uphill field during the day and in the barn during night	Fed in the barn	Fed in a pen beneath the house	Free grazing
Amount and type of feed for adult animal	12 kg fodder grass + 12 kg sugar cane top residue	12 kg fodder grass + 12 kg sugar cane top residue	0.67 kg fodder + 2.33 kg maize	0.063 kg maize + 0.063 kg vegetables	0.063 kg maize + 0.063 kg vegetables
Amount and type of feed for baby animal	-	-	-	-	-
Amount of collected manure	2.5 kg	2.5 kg	1.67 kg	No collection	No collection

Table 85: Alteration of the number of animals. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult buf-falo	1	1	1	1	1	1	1	1	1	1	1	1
Baby buf-falo	0	0	0	0	0	0	0	0	0	0	0	0
Adult cow	4	4	4	4	4	4	4	4	4	2	2	2
Baby cow	0	0	0	0	0	0	0	0	0	2	2	2
Adult duck	17	17	15	15	15	14	14	14	12	12	12	11
Baby duck	0	0	0	0	0	0	0	0	0	0	0	0
Adult chicken	47	44	41	38	35	32	29	26	23	20	17	14
Baby chicken	0	0	0	0	0	0	0	0	0	0	0	0
Adult pig	3	3	3	3	3	3	3	3	3	3	3	3
Baby pig	0	0	0	0	0	0	0	0	0	1	1	1

L Information to farm 9

Table 86: 9

Total amount of maize seeds	0.5 kg (sweet maize)
Crop distance	Between the macadamia trees the distance is 5 m and between longan and mango it is 3 m.
Fishpond	Yes. Water used to irrigate the home garden. 300 kg fish from the pond is eaten by the family each year. Fish is fed 2 kg maize every 3:d day + 30 kg mixed guinea grass and banana trunk every 3:d day. The banana trees and the grass grow next to the pond.
Crop distance	The macadamia trees are planted with no crop distance (¡ 0.2 m) within to the maize and planted with 5 m distance in the field, and the mango and longan has 3 m crop distance
Fodder grass	In total there are five rows, each 80 m long.
Land preperation	To increase the area of farming, land masses was taken from the hill to fill in parts of the pond. This was made last year, so this year is the first year of growing maize and macadamia.

Table 87: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
2	1	0	540 kg rice and 60 kg meat	Burned. Not used for plants	Open toilet. The toilet waste is dug down in a hole far from field, house and the pond. The privy is located next to the house.

Table 88: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree, m^2 or as given in Table.

	1:st input	**2:nd input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Mango	20 kg duck manure + 0.5 kg 6:9:3		20 kg duck manure + 0.5 kg 6:9:3	12 kg	30 kg
Longan	20 kg duck manure + 1 kg 6:9:3		20 kg duck manure + 1 kg 6:9:3	6 kg	12 kg
Guinea grass	0.1 kg Nitrogen rich fertilizer		0.1 kg Nitrogen rich fertilizer	Totally 1825 kg / year	-
Sweet maize	0.1 kg 6:9:3	0.04 kg Nitrogen rich fertilizer	0.1 kg 6:9:3 + 0.04 kg Nitrogen rich fertilizer	No harvest yet	No planting last year
Macadamia	20 kg duck manure		20 kg duck manure	No harvest yet	Not applicable
Vege-tables	8.75 kg chicken manure	8.75 kg chicken manure	17.5 kg chicken manure	total harvest for the whole field is 125 kg in a year	-

Table 89: Crop residue

Mango	**Longan**	**Maize**	**Macadamia**
Big branches are burned for cooking and small ones are left on the field	Big branches are burned for cooking and small ones are left on the field	No crop residue yet	No crop residue yet

Table 90: Field Balance for farm 9

Field number	1	2	3	4
Inflow [kg]				
N	37.7	14.8	0.4	229.8
P	28.74	25.8	0.19	4.5
K	19.27	17.4	0.19	2.96
Outflow [kg]				
N	22.51	0	0.51	0
P	2.74	0	0.055	0
K	44.42	0	0.38	0
Balance [kg]				
N	15.19	14.8	-0.12	229.82
P	26.0	25.8	0.13	4.5
K	-25.15	17.4	-0.18	2.96

Table 91: Animal feed and manure collection. The fodder and manure per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	**Duck**	**Chicken**
Feeding place	In pen located next to home garden	Free grazing
Amount and type of feed for adult animal	more than 21 days: 0.11 kg fodder (F61) + 0.011 kg bought maize + 0.011 kg banana trunk	0.05 kg bought maize
Amount and type of feed for baby animal	0.05 kg fodder (AF plus 3010 1-21 days)	-
Amount of collected manure	0.067 kg	0.01 kg

Table 92: Alteration of the number of animals. the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	**Feb**	**Mar**	**April**	**May**	**June**	**July**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**
Adult duck	0	1000	1000	0	0	1000	1000	0	0	1000	1000	0
Baby duck	1000	0	0	0	1000	0	0	0	1000	0	0	0
Adult chicken	80	78	75	73	70	68	65	63	60	58	55	52
Baby chicken	0	0	0	0	0	0	0	0	0	0	0	0

The farm also keep a fishpond with yearly consumption of 300 kg fish. 0,7 kg maize, 5 kg guinea grass and 5 kg banana trunk is fed to the fishes each day

M Information to farm 10

Table 93: 10

Total amount of maize seeds	5 kg
Fishpond	No
Crop distance	In field 3 and 4 it is 5 m between both trees and rows. In field 1 it is 4 m between trees and 5 m between rows.

Table 94: General household information

Number of Adults >16 years old	**Number of children 9-16 years old**	**Number of children 0-8 years old**	**Amount of bought food during a year**	**Fate of the kitchen waste**	**System and location of privy and its waste**
4	0	1	600 kg rice, 60 kg meat and 24 kg fish	Garbage collector pick up waste	Open toilet. When full, the waste is dug down near the pig pen, behind the house.

Table 95: Crop/ fruit information for the fields. The input is given per trees for fruit trees, and per 1 m^2 field for the crops (rice, soybean and maize), fodder grass and garden. Harvest is stated per tree, m^2 or as given in Table.

	1:st input	**2:nd input**	**Total input**	**Harvest 2022**	**Harvest 2021**
Mango	Field 1: 10 kg pig manure + 1 kg 5:12:3, Field 2: 5 kg cow manure + 1 kg 5:12:3	1 kg 5:12:3	-	5 kg	10 kg
Longan	Field 1: 10 kg pig manure + 1 kg Nitrogen rich fertilizer , Field 2: 10 kg cow manure + 1 kg Nitrogen rich fertilizer	2 kg 5:12:3	-	20 kg	30 kg
Coffee	0.5 kg 5:12:3	-	-	Not yet harvested	1.67 kg
Guinea grass	No fertilization			No harvest	No harvest
Sugarcane	0.03 kg 16:10:14	0.04 kg 20:2:20 TE	0.03 kg 16:10:14 + 0.04 kg 20:2:20 TE	5 kg	-
Vegetables	1.33 kg chicken manure	-	1.33 kg chicken manure	200 kg per year for the entire field	-
Maize	0.1 kg Phosphorous rich fertilizer	0.025 kg Nitrogen rich fertilizer	0.1 kg Phosphorous rich fertilizer + 0.025 kg Nitrogen rich fertilizer	0.6 kg	-
Rice	50 kg Phosphorous rich fertilizer for the entire field	50 kg Phosphorous rich fertilizer for the entire field	100 kg Phosphorous rich fertilizer	400 kg in total	-

Table 96: Crop residue

Mango	Longan	Sugarcane	Coffee	Maize	Rice
Big branches are burned for cooking	Big branches are burned for cooking	Left on the field	Left on the field	Left on the field	Fresh straw is given to the animals

Table 97: Field Balance for farm 10

Field number	1	2	3	4	5	6	7
Inflow [kg]							
N	17.64	128	3.86	185.1	1.01	23	0
P	11.5	6.09	3.69	42.48	0.32	17.44	8.72
K	6.07	116.2	2.9	43.14	0.25	0	0
Outflow [kg]							
N	1.79	137.25	0.44	11.4	0.82	15.6	4.2
P	0.36	20	0.047	1.38	0.088	2.32	0.8
K	10.79	238	0.48	13.2	0.6	5.16	1
Balance [kg]							
N	15.85	-9.25	3.41	173.7	0.19	7.4	-4.2
P	11.14	-13.91	3.65	41.1	0.23	15.11	7.92
K	-4.72	-121.8	2.42	29.94	-0.35	-5.16	-1

Table 98: Animal feed and manure collection. The fodder per kind of animal is calculated for one entity. The fodder and collected manure is a measure of daily feed and collection.

Kind of animal	**Pig**	**Chicken**
Feeding place	Fed in the barn	Free grazing
Amount and type of feed for adult animal	1 kg fodder + 1 kg vegetables from the farm + 1 kg maize from the farm	0.033 kg maize + 0.01 kg rice
Amount and type of feed for baby animal	milk	0.033 kg maize + 0.01 kg rice
Amount of collected manure	Cannot answer	40 kg in total during 1 year

Table 99: the table shows the number adult and baby animals for each kind of animal for each month during the year.

	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Adult pig	1	1	1	1	1	1	1	1	1	1	1	1
Baby pig	0	0	0	0	0	0	0	6	0	0	0	0
Adult chicken	100	95	91	51	21	18	14	10	30	27	23	20
Baby chicken	0	0	0	0	0	25	25	25	0	0	0	0

The pig fodder is either made from the residues of beer brewing or bought fodder (D88)