Internal flow of nutrients in organic farming systems in tidal swamp

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Abstract. Sustainable nutrient management is critical to the success of an agroecosystem. The potential of nutrient flow to agroecosystems in tidal swamps can be observed in several soil and water management. Tidal swamp land management based on surjan and tabukan system are often used to farm several sub-agicultures, namely rice fields, ponds, and citrus plantations. This study aimed to determine N nutrients' input, output, and internal flow in organic farming systems. This study is limited to observing the internal components. The integrated organic farming system in tidal swampland, usually used for orange in the raised beds and rice in the sunken beds/wetland sections or fishponds, demonstrated the potential for inorganic N-flow between farming sub-systems and between components within the system. Scenarios for the use of rice straw for external production sub-systems such as for citrus plantations and composting for external purposes need consideration. This potential can be a sub-component of nutrient input for other sub-systems or the next planting season. The simulation of the integrated rice-citrus-fishpond agroecosystem model showed a positive nutrient balance, especially N nutrients. This model needs to be further developed.

1. Introduction
Swampland has various benefits for humans and the environment, one of which is its potential as productive agricultural land [1]. There is an interaction between soil, water, and plants in achieving sustainable agricultural productivity [2]. The utilization of tidal swampland for agricultural land faces many constraints that are mainly related to the water and soil characteristics [3-5]. Water problems include those related to high tide on the land, stagnant water in the land [6] and the occurrence of excessive drainage [7, 8]. Whereas the soil problems mainly include acid soil reactions, the potential for pyrite, which will cause acidity if not carefully controlled [9, 10], and high nutrient mobility, especially nitrogen (N) and nutrients [4, 5]. Farmers in Banjar and transmigrants in South Kalimantan, particularly in Barito Kuala District, have made applies surjan (raised beds) and tabukan (sunken beds) system [5, 11-12]. The construction of these beds is intended to provide adequate drainage to the root environment. Otherwise, the rhizosphere will always be wet, thus causing air scarcity and preventing the plant roots from growing [13]. In addition, this type of land arrangement allows farmers to do multi farming, such as citrus-orange, rice-citrus-fish, or rice-citrus-poultry.

Tidal lands are generally known to have developed various sub-systems of agricultural businesses (mixed farming). The input used in each sub-system is mainly obtained from the external so that the production input (energy) required is high. The development of an integrated farming system in the tidal
land of Barito Kuala is a suitable alternative to reduce production inputs through a biological cycle (biocycle farming) [14]. Biocycle farming will streamline the flow of energy from various agricultural sub-systems, where waste from one agricultural business can be utilized by other agricultural businesses and so on. Therefore, the energy needed from each agricultural business can be fulfilled and efficient in this system. The existence of an energy flow that can meet the needs of a system resulting from a biological cycle of various agricultural businesses is a characteristic of an integrated agricultural system [14, 15, 16]. Waste generated by one agricultural business can be utilized by other agricultural businesses. To ensure that the biocycle farming process runs, information on the potential flow of materials in the farming system is needed.

The conditions in the field show that local farmers and transmigrants in Barito Kuala Regency, South Kalimantan Province, have long used tidal swampland for agricultural activities, especially for rice and fruit farming. However, currently they are faced with a decline in land quality, especially water and soil quality. As a result, agricultural production capacity decreases. In some locations, there has been a segmentation of soil quality characterized by rice production segmentation. To design a model for the flow of materials and energy in an integrated farming system, it is necessary to study the product's potential and its by-products. Nutrient N is essential for agricultural production in wetlands, including tidal land. However, the availability of N nutrients comes from external flows, which is a source of N fertilizer, and internal flows. Such condition is a significant problem related to N nutrient availability in tidal land agroecosystems. It is essential to understand the internal flow of N to support the N availability internally. Thus it is not necessary to apply N fertilizer. This research was critical to place the importance of organic farming in promoting the availability of N in tidal land agroecosystems [15] [17-25]. This research was specifically to analyze the potential of the N balance on the balance of input and output at the inlet and outlet at a depth of the surjan soil.

2. Materials and methods

2.1. Research site

This research was carried out on direct tidal land classified in the subcategories of A and B soil types, potentially sulfuric acid soil with pH ranges from 4 - 5 (based on preliminary observations). The location was in Barito Kuala Regency. Observations were done during the rainy season from mid-October 2011 until the end of January 2012. Agricultural activities that are often carried out by farmers generally consist of two parts of the land, namely surjan which are often used by farmers for citrus and various vegetables farming. And the tabukan area is often used for rice plant and pa of a fishpond. The utilization of land units from farmers is often used to optimize the function of water flow in nutrient management, especially the element N.

2.2. Research design

This research is a descriptive study that describes the potential flow of inorganic N (NH₄⁺ and NO₃⁻) in agro-aquaculture systems in tidal swampland. The system refers to the existing farming system in tidal swampland. Land use with the surjan systems is often applied in tidal swampland. This study was limited to observing the potential for inorganic N-flow in the surjan and tabukan sub-systems planted with oranges and other sub-system cultivated for fishponds. The flow sketch is as shown in Figure 1. Between farming sub-systems, material flows (especially residues). So that they can be a source of materials and energy for production processes in other sub-systems. Overall, it is expected that there will be efficiency and optimization of residue utilization in the production process.
Furthermore, the inorganic N (N-NH + and N-NO -) observed during the rainy season was distinguished according to the depth of the soil; Soil at a depth of 0-20 cm, the fraction is 0.9, the soil at the next 30 cm depth is 0.1, and at the next depth, it is assumed the fraction is 0 (no contribution from rainwater). Rainwater input capacity (IN1) is calculated as follows:

\[
IN1 = \text{mean N rainwater (mg l}^{-1} \text{)} \times \text{volume of rainwater (l m}^{-2} \text{)} \times \text{total soil porosity x water pore fraction field capacity x soil thickness (m) x fraction of rainwater contributing to water soil relative to other water sources x 10}^{-2} \text{ (conversion to kg ha}^{-1} \text{).}
\]

The total porosity of the soil used was 0.56 (the preliminary research), and the pore water fraction of the field capacity was assumed to be 0.5 part of the total porosity of the soil. The fraction of rainwater that contributes to groundwater is distinguished according to the depth of the soil; Soil at a depth of 0-20 cm, the fraction is 0.9, the soil at the next 30 cm depth is 0.1, and at the next depth, it is assumed the fraction is 0 (no contribution from rainwater).

- The inlet or river water input capacity (IN2) is calculated as follows:

\[
IN2 = \text{mean N river water (mg l}^{-1} \text{)} \times \text{total soil porosity x water pore fraction field capacity x soil thickness (m) x soil area 1 m}^2 \times 10^3 \text{ (conversion m}^3 \text{ to l) x fraction river water}
\]
is in the soil per unit of time x fraction of river water contributes to groundwater x \(10^{-2}\) (conversion mg m\(^{-2}\) to kg ha\(^{-1}\))

The fraction of river water in the soil per unit time is assumed to be 0.1 in the soil at a 0-20 cm, 0.25 at the next 30 cm depth, and 1.0 at the next depth. The fraction of river water that contributes to groundwater is distinguished according to the depth of the soil; Soil at a depth of 0-20 cm has a fraction of 0.1, the soil at a depth of the next 30 cm is 0.9, and at the next depth the fraction is assumed to be 1.0 (meaning that this layer of soil water only comes from river water).

- The output capacity of drainage or outlet water (OUT3) is calculated as follows:

\[
\text{OUT3 (kg ha}^{-1}\text{)} = \text{mean N river water (mg l}^{-1}\text{)} \times \text{total soil porosity} \times \text{drained water pore fraction} \times \text{soil thickness (m)} \times 1 \text{ m}^2 \text{ land area} \times 10^3 \text{ (m}^3\text{ to l conversion)} \times \text{water fraction river is in soil per unit time} \times \text{fraction of river water contributes to groundwater} \times 10^2 \text{ (conversion mg m}^{-2}\text{ to kg ha}^{-1}\text{)}
\]

The drainable porosity fraction is assumed to be 0.5. This assumption is that the porosity of saturated and unsaturated water on tidal land, respectively is assumed to be in the fraction of 0.5.

- The internal flow capacity of the pond slurry (IF1) is calculated as follows:

\[
\text{IF1 (kg ha}^{-1}\text{)} = \text{mean inorganic N of sludge (mg kg}^{-1}\text{)} \times \text{weight of sludge per unit area (kg m}^2\text{)} \times 10^{-2} \text{ (conversion of mg m}^{-2}\text{ to kg ha}^{-1}\text{)}
\]

The capacity of other input sub-components such as fertilizer (IN3) is equal to 0 because it is not fertilized; and fish feed (IN4) is not observed and is assumed to be 0 to calculate the N system balance. The capacity of other output sub-components such as crop yields (OUT1) and fish yields (OUT2) is calculated according to the balance sheet. Furthermore, the internal flow capacity of plant residues (IF2) was not observed and was assumed to be 0.

- The overall system N capacity is calculated as follows:

\[
\text{Total capacity (kg ha}^{-1}\text{)} = \text{IN1} + \text{IN2} + \text{IN3} + \text{IN4} + \text{IF1} + \text{IF2}
\]

\[
\text{Net capacity (kg ha}^{-1}\text{)} = \text{IN1} + \text{IN2} + \text{IN3} + \text{IN4} + \text{IF1} + \text{IF2} - \text{OUT3}
\]

3. Results and discussion

This study has described changes in N in the form of NH\(_4\) and NO\(_3\). The changes are described based on the depth of the soil and its position at the inlet and outlet of the surjan area. The soil depth section is based on water saturation status, which consists of unsaturated water depth, transition depth, and always saturated water depth for most of the year. Thus, in general, the depth of observation in this study is 0 - 20 cm, 20 - 50 cm, and 50 - 100 cm. Meanwhile, for each part of the water that enters (inlet) and part that comes out (outlet). The N balance in the surjan soil has been observed at the inlet and outlet for each input, output, and balance (Table 2) [16, 19, 26, 27, 28].
Table 2. Balance on the inlet and outlet surjan system.

| SURGES SYSTEM WITH INLET LINE AND POOL | 1 m | 0.5 m | 0.2 m |
|----------------------------------------|-----|-------|-------|
| 1 METER THICKNESS                       | N-NH₄ | N-NO₃ | N | N-NH₄ | N-NO₃ | N | N-NH₄ | N-NO₃ | N |
| INPUT                                  | kg ha⁻¹ | kg ha⁻¹ | . | kg ha⁻¹ | kg ha⁻¹ | . | kg ha⁻¹ | kg ha⁻¹ | . |
| Rainwater                               | 0.5 | 1.5 | 2.0 | 0.5 | 1.5 | 2.0 | 0.5 | 1.5 | 2.0 |
| River Water                             | 0.8 | 1.4 | 2.2 | 0.8 | 1.4 | 2.2 | 0.8 | 1.4 | 2.2 |
| Pool Base Mud                           | 2.0 | 13.8 | 15.8 | 2.0 | 13.8 | 15.8 | 2.0 | 13.8 | 15.8 |
| Fish Pool Water                         | 11.5 | 30.5 | 42.0 | 3.4 | 16.6 | 20.0 | 2.5 | 15.0 | 17.5 |
| OUTPUT                                  | . | . | . | . | . | . | . | . | . |
| Fish Pool Water                         | 5.5 | 28.5 | 33.9 | 0.5 | 2.6 | 3.1 | 0.0 | 0.0 | 0.0 |
| Potential Nutrients                     | 6.1 | 2.0 | 8.1 | 2.9 | 14.1 | 16.9 | 2.5 | 15.0 | 17.5 |
| Balance                                 | 11.5 | 30.5 | 42.0 | 3.4 | 16.6 | 20.0 | 2.5 | 15.0 | 17.5 |

| SURJAN SYSTEM WITH OUTLET LINE AND POOL | 1 m | 0.5 m | 0.2 m |
|----------------------------------------|-----|-------|-------|
| 1 METER THICKNESS                       | N-NH₄ | N-NO₃ | N | N-NH₄ | N-NO₃ | N | N-NH₄ | N-NO₃ | N |
| INPUT                                  | kg ha⁻¹ | kg ha⁻¹ | . | kg ha⁻¹ | kg ha⁻¹ | . | kg ha⁻¹ | kg ha⁻¹ | . |
| Rainwater                               | 0.5 | 1.5 | 2.0 | 0.5 | 1.5 | 2.0 | 0.5 | 1.5 | 2.0 |
| Fish Pool Water                         | 5.5 | 28.5 | 33.9 | 0.5 | 2.6 | 3.1 | 0.0 | 0.0 | 0.0 |
| Pool Base Mud                           | 2.0 | 13.8 | 15.8 | 2.0 | 13.8 | 15.8 | 2.0 | 13.8 | 15.8 |
| Water Drainage                          | 8.0 | 43.7 | 51.7 | 3.0 | 17.8 | 20.9 | 2.5 | 15.0 | 17.5 |
| OUTPUT                                  | . | . | . | . | . | . | . | . | . |
| Water Drainage                          | 4.7 | 14.5 | 19.2 | 0.4 | 1.3 | 1.7 | 0.0 | 0.0 | 0.0 |
| Potential Nutrients                     | 3.4 | 29.2 | 32.6 | 2.6 | 16.5 | 19.1 | 2.5 | 15.0 | 17.5 |
| Balance                                 | 8.0 | 43.7 | 51.7 | 3.0 | 17.8 | 20.9 | 2.5 | 15.0 | 17.5 |

At the inlet and the thickness of 1 meter, the N balance is as follows. The N input comes from rainfall, river water and fishpond mud. Each part is 2.0, 24.2 and 15.8 N kg/ha or a total of 42.0 N kg/ha for 3 months from November to January in the rainy season. The output of N is 32.9 N kg/ha for pond water, and the remaining part of the surjan are planted with vegetables and citrus, which is balanced at 8.1 N kg/ha. As is the case with the illustration above, yields of the same crop yielded 16.9 and 17.5 N kg/ha at depths of 0.5 and 0.2 meters. At the outlet and a thickness of 1 meter, the N balance is the same as before. Input N comes from rainfall, pond water and fishpond mud. Each part is 2.0, 33.9 and 15.8 N kg/ha or a total of 51.7 N kg/ha for 3 months from November to January in the rainy season. The output of N is the drainage water of 19.2 N kg/ha and the remaining part of the surjan planted with vegetables and citrus, which is balanced at 32.6 N kg/ha. As is the case with the illustration above, yields of the same crop yielded 19.1 and 17.5 N kg/ha at 0.5 and 0.2 meters depth, respectively. The above indication shows that the productivity of N in each surjan section and the inlet and outlet sections. In farming without the use of fertilizers can provide N nutrients in this study. The better product of N in the surjan section is at the outlet. Thus, it is essential in organizing farming units so that crop productivity can be optimized. In naturally inundated agroecosystems such as swamps, the input (input) of river water must be balanced with the output (output) in the form of drainage water, and the net N capacity can potentially be utilized for biomass production.

Each sub-component in the integrated farming system in tidal swampland has the potential for materials to be channeled to complement each other’s material needs (N-inorganic) for the biomass production process. The subcomponents of pond water pond mud, rainwater, tidal river water, and plant residues have the potential to be managed optimally as input components for agroecosystems. Its management must meet the principle of balance between input and output components, so that no residue is not utilized, or all materials are included in the agroecosystem. The balance of this material (nutrient) can be used as an indicator of the sustainability of the agroecosystem. Classified biomass production systems based on their nutrient balance into 3 (three) conditions: (1) if the amount of input is higher than the amount of output then the stock of nutrients in the soil increases; (2) if the amount of input is
lower than the amount of output then the stock of nutrients in the soil decreases, and (3) if the amount of input is equal to the amount of output, then the stock of nutrients in the soil is constant [14, 16, 28, 29]. Agroecosystem sustainability can only be achieved if the number of inputs is equal to the number of outputs (in a balanced state).

Table 3. The potential flow of inorganic N (kg ha\(^{-1}\)) in agro-aquaculture systems (d = 1 meter) with several scenarios of the ratio of storm area and pond area during the rainy season period (November 2011 – January 2012).

| Scenario | Area (ha) | IN1 | IN2 | IN3 | IN4 | OUT1 | OUT2 | OUT3 | IF1 | IF2 | System Capacity |
|----------|-----------|-----|-----|-----|-----|------|------|------|-----|-----|-----------------|
| Surjan   | 0.3       | 3.9 | 41.4| 0.0 | 0.0 | 31.5 | 0.0  | 24.9 | 11.1| 0.0 | 56.4            |
| Pool     | 0.7       | 9.2 | 96.7| 0.0 | 0.0 | 0.0  | 36.7 | 58.1 | 0.0 | 0.0 | 105.8           |
| Surjan   | 0.4       | 5.2 | 55.3| 0.0 | 0.0 | 36.8 | 0.0  | 33.2 | 9.5 | 0.0 | 70.0            |
| Pool     | 0.6       | 7.8 | 82.9| 0.0 | 0.0 | 0.0  | 31.4 | 49.8 | 0.0 | 0.0 | 90.7            |
| Surjan   | 0.5       | 6.5 | 69.1| 0.0 | 0.0 | 42.0 | 0.0  | 41.5 | 7.9 | 0.0 | 83.5            |
| Pool     | 0.5       | 6.5 | 69.1| 0.0 | 0.0 | 0.0  | 26.2 | 41.5 | 0.0 | 0.0 | 75.6            |
| Surjan   | 0.6       | 7.8 | 82.9| 0.0 | 0.0 | 47.2 | 0.0  | 49.8 | 6.3 | 0.0 | 97.0            |
| Pool     | 0.4       | 5.2 | 55.3| 0.0 | 0.0 | 0.0  | 21.0 | 33.2 | 0.0 | 0.0 | 60.5            |
| Surjan   | 0.7       | 9.2 | 96.7| 0.0 | 0.0 | 52.5 | 0.0  | 58.1 | 4.7 | 0.0 | 110.6           |
| Pool     | 0.3       | 3.9 | 41.4| 0.0 | 0.0 | 0.0  | 15.7 | 24.9 | 0.0 | 0.0 | 45.4            |

IN1 = rainwater, IN2 = River water, IN3 = fertilizer, IN4 = feed, OUT1 = crop yield, OUT2 = fish yield, OUT3 = drainage water, IF1 = pond mud internal flow, and IF2 = plant residue.

Based on the principle of sustainability and the potential of N flow, several scenarios of land management for agro-aquaculture systems can be developed. Table 3 describes the input-output system in the agro-aquaculture system with several scenarios of comparison of the area of surjan and pond area. Each scenario shows the potential of the system to provide nutrient N for biomass production (plants and fish). For example, at the ratio of the area of surjan and pond area of 3:7, available nutrients observed were 31.5 and 36.7 kg N, respectively. The results indicated that the tidal swamp land agroecosystem has its own ability to supply nutrients for biomass production. This implies that the production of biomass in tidal swampland does not always require fertilization (fertilizer from outside), but it is sufficient to optimize the flow of nutrients internally. In line with this, [16] reported that agricultural systems with low external input (low external input agriculture) were able to maintain the level of fertility of agricultural soils compared to conventional farming systems. Such an approach guarantees the sustainability of the farming system in tidal swampland.

4. Conclusion
It is concluded that an integrated farming system in tidal swampland, which is usually planted with oranges in the surjan system, and rice is planted in the tabukan section or fishponds implies the potential for inorganic N-flow between farming sub-systems and between components within the system. The potential for flow in the system can be considered to formulate a fertilization strategy in tidal swamp agroecosystems. River water, rainwater, and fishpond water implies an influence on the inorganic N content of the surjan soil. The fishpond mud has the potential to increase the N-inorganic content of the surjan soil. The use of rice straw needs to be carried out for external production sub-systems such as citrus plantations or composting for external purposes.
References

[1] Brander L, Brouwer R and Wagtendonk A 2013 Economic valuation of regulating services provided by wetlands in agricultural landscapes: A meta-analysis Ecol. Eng. 56 89–96

[2] Arnold J G, Allen PM and Morgan D S 2001 Hydrologic model for design and constructed wetlands Wetlands 21 167–178

[3] Patil M D, Das BS and Bhadoria P B S A simple bund plugging technique for improving water productivity in wetland rice Soil Tillage Res. 112 66–75

[4] Reddy K R, DAngelo E M and Harris W G 2000 Biogeochem of Wetlands CRC Press. Handbook of Soil Science pp G89-119

[5] Heal K V 2014 Constructed wetlands for wastewater management Water Resour. Built Environ. Manag. Issues Solut., 9780470670 pp 336–349

[6] Epaphras A M, Greta E, Lejora I A and Mtahiko M G G 2007 The importance of shading by riparian vegetation and wetlands in fish survival in stagnant water holes, Great Ruaha River, Tanzania Wetland Ecol. Manag. 15 329–333

[7] Vymazal J 2017 The use of constructed wetlands for nitrogen removal from agricultural drainage: A review Sci. Agric. Bohem. 48 82–91

[8] Sulaiman A A, Sulaeman Y and Minasny B 2019 A framework for the development of wetland for agricultural use in Indonesia Resources 8 1–16

[9] Fahmi A, Radjagukguk B and Purwanto B H 2015 Interaction of peat soil and sulphidic material substrate: Role of peat layer and groundwater level fluctuations on phosphorus concentration J. Trop. Soils 19 171-179

[10] Fahmi A, Nurzakiah S and Susilawati A 2019 The interaction of peat and sulphidic material as a substrate in a wetland: Ash content and electrical conductivity dynamic IOP Conf. Ser. Earth Environ. Sci. 393 012045

[11] Ratule M T, Sutopo, Aji T G, Fanshuri B A and Dwiaestuti M E 2020 The potential of intercropping citrus and rice to improve the productivity of swampland in Indonesia IOP Conf. Ser. Earth Environ. Sci. 484 012052

[12] Ndlovu C and Manjeru L 2014 The influence of rituals and taboos on sustainable wetlands management: The case of Matobo District in Matabeleland South Province Int. J. Sci. Res. Publ., 4 2250–3153

[13] de Kroon H, Padilla F M, Hendriks M, van Ruitjven J, Ravenel J, Jongeijans E, Visser E J W and Mommer L 2012 Root responses to nutrients and soil biota: Drivers of species coexistence and ecosystem productivity J. Ecol. 100 6–15

[14] Möller K 2018 Soil fertility status and nutrient input-output flows of specialized organic cropping systems: A review Nutr Cycl Agroecosyst vol 30 August 2018

[15] Nemecek T, Dubois D, Huguenin-eifie O and Gaillard G 2011 Life cycle assessment of Swiss farming systems: I. Integrated and organic farming Agric. Syst., vol. 104, no. 3, hal. 217–232, 2011, doi: 10.1016/j.agsy.2010.10.002.

[16] De Jager A, Onduru D, Van Wijk M S and Vlaming J 2001 Assessing sustainability of low-external- input farm management systems with the nutrient monitoring approach: a case study in Kenya Agricultural Systems 69 99–118

[17] Musyoka M W, Adamtey N, Muriuki A W, Bautze D, Karanja E N and Komi M M 2019 Nitrogen leaching losses and balances in conventional and organic farming systems in Kenya Nutr. Cycl. Agroecosystems 114 237–260

[18] Pj M, Naheem M and Mubafar R 2016 New aspect for organic farming practices Controlled crop Nutrition and Soilless Agriculture 1–6

[19] Reddy BS 2010 Organic farming: Status, issues, and prospects – A review Agricultural Economics Research Review 23 343-358

[20] Taylor P, Alonso A M and Guzmán G J 2014 Comparison of the efficiency and use of energy in organic and conventional farming in Spanish agricultural systems Journal of Sustainable Agriculture 37-41
[21] Goulding K, Stockdale E and Watson C 2008 Plant nutrients in organic farming Organic Crop Production – Ambitions and Limitations H. Kirchmann, L. Bergström (eds.) Springer Science+Business Media B.V 73–88

[22] Taylor P, Macrae R J, Lynch D, and Martin R C 2014 Improving energy efficiency and GHG mitigation potentials in Canadian organic farming systems 37–41

[23] Zikeli S, Deil L, and Möller K 2017 The challenge of imbalanced nutrient flows in organic farming systems: A study of organic greenhouses in Southern Germany Agric. Ecosyst. Environ. 244 1–13

[24] Nowak B, Nesme T, David C and Pellerin S 2013 To what extent does organic farming rely on nutrient inflows from conventional farming? Environ. Res. Lett. 8 044045 (8pp)

[25] Kirchmann H and Bergström L 2001 Do organic farming practices reduce nitrate leaching? Communications in Soil Science and Plant Analysis 32 997-1028

[26] Khai N M, Ha P Q, and Öborn I 2007 Nutrient flows in small-scale peri-urban vegetable farming systems in Southeast Asia — A case study in Hanoi Agriculture, Ecosystems and Environment 122 192–202

[27] Reimer M, Möller K and Hartmann T E 2020 Meta-analysis of nutrient budgets in organic farms across Europe Org. Agr. 10 S65–S77

[28] Van den Bosch H, De Jager A and Vlaming J 1999 Monitoring nutrient flows and economic performance in African farming systems (NUTMON) II. Tool development Agriculture, Ecosystems and Environment 71 49-62

[29] Oelofse M, Lucimar H H and De Neergaard A 2010 A comparative study of farm nutrient budgets and nutrient flows of certified organic and non-organic farms in China pp 455