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Macro-primary nutrient balances in flood recession agriculture on maize fields: A Case Study of the Chikwawa District, Malawi

Practical Note

Flood-Based Livelihoods Network Foundation

Flood-Based Livelihoods Network Malawi

Rainwater Harvesting Association of Malawi

Making sure every drop counts

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1. Introduction

This Practical Note is a result of field experiments (adaptive research trials) that took place in Malawi in 2019. These adaptive research trials comprised of 5 different nutrient management options in flood-recession agriculture. These different treatments regarding input of nutrients have been studied and nutrient balances been compiled.

Area

The experiments took place in the Chikwawa district, which is located in the south of Malawi (figure 1), in the Lower Shire valley. This name refers to its low altitude, expressed in MASL (metres above sea level) in figure 3 (Adeloye et al., 2015). Chikwawa district is characterized by high poverty rates and annual floods (National Statistical Office, 2019). Livelihoods are mainly derived from subsistence agriculture, with a strong focus on maize (Adeloye et al., 2015). Maize is grown on 70% of the fields in Malawi, with an average yield of about 2 ton/hectare for smallholder farmers. However, currently cultivated maize varieties have potential yields of 6 to 10 ton/hectare. The difference between potential and actual yield is caused by an overexploited soil, lack of water and nutrients and mismanagement.

Figure 1 Malawi

Flood-recession agriculture

Farmers try to beneficially use the flood water in order to overcome the dry spells following the floods. This form of agricultural cultivation is called flood recession agriculture and takes place in the wetlands, locally known as dambos, adjacent to the Shire river (figure 4) (Chidanti-Malunga, 2009). Flood recession agriculture is also referred to as floodplain agriculture and floodplain irrigation. Contrary to the common agricultural cycle in Malawi, maize in the wetlands is planted at the end of the rainy season, which lasts from November to April. The dry season, which lasts from May to October, is then used for the cultivation of maize.

Figure 2 Floods are receding prior to planting

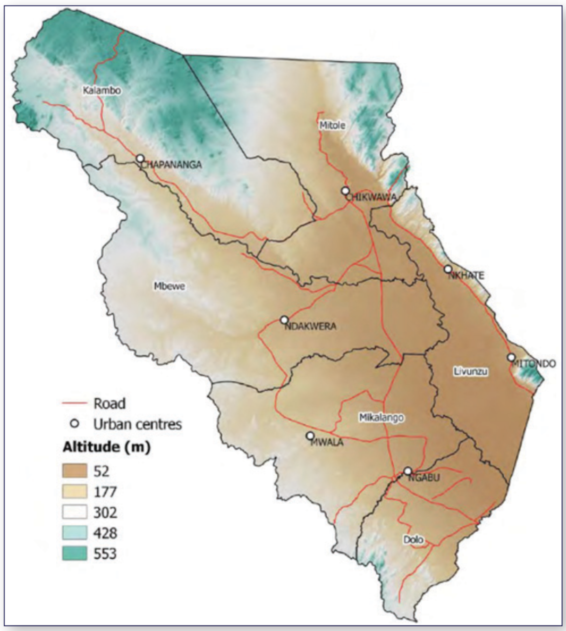


Figure 3 Chikwawa district, altitude (Omuto & Vargas, 2019)

Nutrients

In flood-recession agriculture, farmers generally do not apply fertilizer or manure, as they believe it is not worth the investment and not necessary, as nutrients will come with the floods (Khan et al., 2014). However, limited extra inputs in terms of manure or fertilizer, are expected to drastically increase the yields.

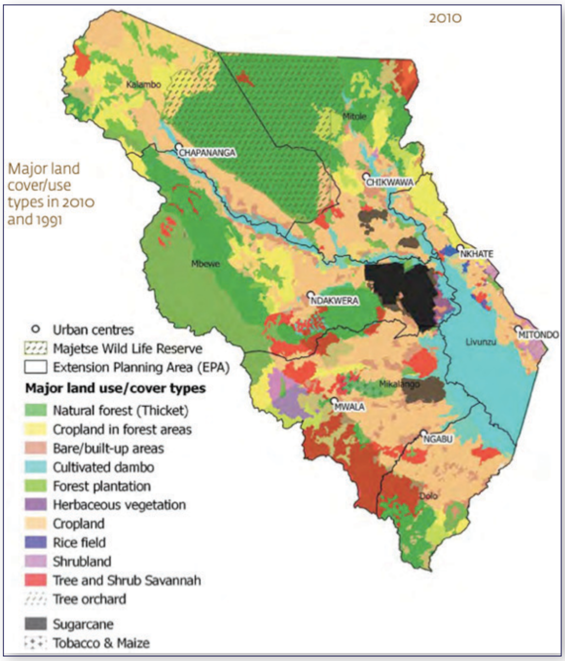


Figure 4 Chikwawa district, land cover and land use 2010 (Omuto & Vargas, 2019)

In Malawi, soil fertility has declined a lot during the past decades (Roy et al., 2003). This is caused by erosion (Henao & Baananta, 1999), limited use of fertilizer and manure and mismanagement. The continuous monocropping of maize is another factor contributing to a decrease in soil fertility (Veldman, 2012). The increased use of fertilizers in the 21st century was still insufficient to prevent soil nutrient depletion (Nalivata et al., 2017). This makes it interesting to dive into the nutrient balances of flood-based systems, which seem to have the advantage of nutrient inflow with the floods, in comparison with other systems.

A high potential for production increase in flood-recession agriculture, comes together with high nutrient depletion rates in Malawian soils. Combining an increase in yield with a neutral or positive soil nutrient balance, in order to respectively not further exploit and restore the soil fertility, is a challenge.

Macro-primary nutrients are needed in large amounts for plant growth. These nutrients are nitrogen, phosphorus and potassium, commonly known as N, P & K. Other macro and micro nutrients are required in lesser quantities, and are often relatively more available in African soils than N, P & K. (Jones Jr, 2002). Following this reasoning, this practical note focusses on the macro-primary nutrients and not on other nutrients.

Nutrient balance

The nutrient balance is defined as the difference between the nutrient inputs entering a farming system and the nutrient outputs leaving the system. This balance has to be made up per nutrient, in this case for N, P and K. To make up this balance, the inputs and outputs of a specific nutrient have to be considered. An example of a scheme including all the nutrient in- and outflows in the soil is displayed in figure 5. The abbreviations of inputs and outputs are displayed in brackets.

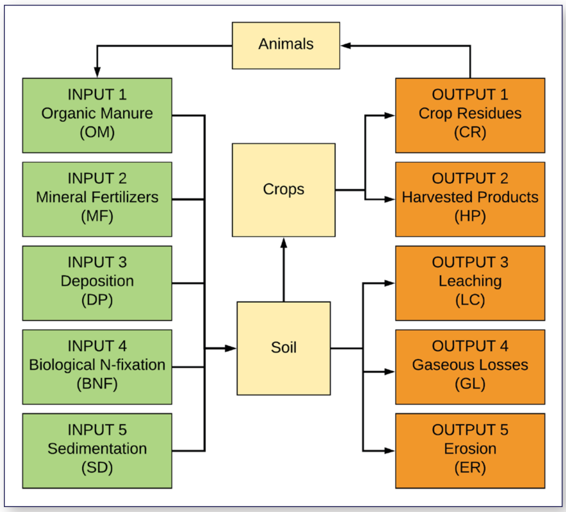


Figure 5 Nutrient in- and outflows (edit from (Roy et al., 2003))

2. Adaptive research trials

Procedure

The ARTs were located in the dambos in the Dolo Extension Planning Area (EPA), the most southern EPA in Chikwawa district (figure 3). The set-up that has been used for the ARTs on nutrient management was the following: a field was divided into 20 plots, each planned to measure approximately 6m^2. These plots have been treated differently regarding the input of fertilizer and manure. This was, for as far as possible, the only factor that was different among the plots.

Five different treatments regarding nutrient input have been applied. Each treatment has been applied to four plots. In table 1, the different treatments are described shortly. In figure 6, a sketch of the layout of the experiment area is displayed. The numbers behind the dashes in figure 6, indicate the replicate number.

Table 1 Treatments on ARTs

Nr.	Reference	Treatment Name	Description
1	OO	OO - Organic Manure Only	Organic Manure applied at the time of planting + Organic Manure applied as top dressing after 21 days
2	FO	FO – Inorganic Fertilizer and Organic Manure	Organic Manure applied at the time of planting + Inorganic Fertilizer (Urea) applied as top dressing after 21 days
3	FP1	FP1 – Farmer Practice 1	Inorganic Fertilizer (Urea) applied as top dressing after 21 days
4	FP2	FP2 – Farmer Practice 2	No inorganic fertilizer nor manure
5	FR	FR – Fertilizer Recommended	NPK and Urea fertilizer applied as basal dressing at the time of planting + Inorganic Fertilizer (Urea) applied as top dressing after 21 days

Plot 1 OO - 1	Plot 2 OO - 4	Plot 3 OO - 3	Plot 4 FP1 - 4	Plot 5 FO - 4
Plot 6 FP2 - 1	Plot 7 FO - 3	Plot 8 FO - 2	Plot 9 FP2 - 4	Plot 10 OO - 3
Plot 11 FP1 - 2	Plot 12 FR - 1	Plot 13 FP1 - 1	Plot 14 FO - 1	Plot 15 FR - 4
Plot 16 FP1 - 3	Plot 17 FP2 - 3	Plot 18 FP2 - 3	Plot 19 FR - 2	Plot 20 FR - 3

Figure 6 Sketch of ARTs layout, including references and replicate numbers (source: own compilation)

Figure 7 Demarcating of the plots which received different treatments

Maize variety DK8033[1] was cultivated on all plots. DK8033 is a short season hybrid, with a duration of 120-130 days. DK8033 has a potential yield of 8000 kg/hectare and is recommended to be grown on low to medium altitudes. Short season hybrids are suitable for FBLS, where water is often lacking later in the season, when soil moisture is getting depleted. The actual yield of this variety in Malawi is 2 to 3 ton/hectare (Secretary for Agriculture and Food Security, 2012). Extrapolation of the yields measured on the small plots, made it possible to calculate yields per hectare. These data have also been used to compile part of the nutrient balances.

Figure 8 Data collection on ARTs

Within the ARTs, only the input of nutrients was considered as a factor that differed amongst the treatments and plots. This assumption is reasonable, because all the other factors, of which some are discussed below, were equal for the 20 plots.

- The **location** for all the plots was considered equal, as they were all located directly next to each other on the same field.
- The **slope** of the field was close to 0%, and thus considered neglectable for all plots.

[1] More information about this specific variety can be found on the website of Monsanto: http://www.monsantoafrica.com/products/seeds_traits/dekalb.asp.

- **Flood water** for all the plots was equal. Prior to planting, a flood of 2-3 meters high had flooded the field. After recession of the flood water, the maize crop was planted.

- **Soil** conditions prior to planting were considered equal for the whole field. In the years before the experiment, the whole field has been treated equally and used for maize only.

- Following a neglectable slope and equal soil conditions, the **soil moisture conditions** at planting could be considered equal for all the plots.

- **Supplemental irrigation** took place when necessary, in order to prevent water stress. Farmers decided whether and when this was necessary. It is assumed that this was equal for all plots. For this reason, it was estimated that there was no **water stress** on any of the plots.

- The same **planting method** has been used in all the plots, which is Sasakawa planting (figure 9). This means that planting is done in rows that are 75cm apart, in which plants are 25 cm apart from each other, with a single seed at each planting station. When one hectare is planted this way, 53 333 crop stands are counted.

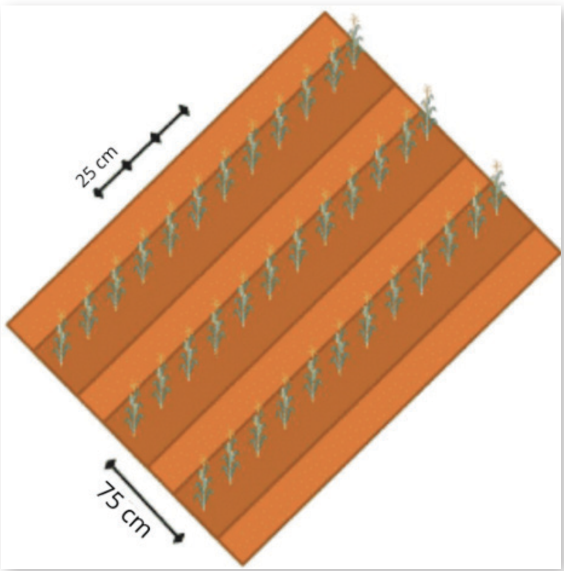


Figure 9 Sasakawa planting (edited from (Veldman, 2012))

- The same **seeding method** has been used in all the plots, which was direct hand-seeding.

- On all the plots, the same **weed control** measures have been applied. Glyphosate (Roundup) has been applied at a rate of 2.5 litre/hectare when weeds were present at seeding. The spraying always took place before the maize emerged. Soon after planting pre-emergence herbicide has been applied. After crop emergence, careful and superficial manual weed control took place. Short before or at harvest late weed control took place, in order to avoid weeds setting seeds.

Basal dressing

A basal dressing is defined as the manure and/or fertilizer applied at the time of sowing. It ideally provides nutrients which are slowly released over the growing season, and nutrients needed by the crop early in its growing cycle.

Two basal dressings have been used for the ARTs: fertilizer and manure.

- o **Fertilizer**

- The fertilizer has been applied 12.5 cm away from the planting station and 10 cm deep at either side of the plant.

- A mix of 23:10:5 + 6S (sulphur) + 1.0Zn (zinc) (referred to as NPK fertilizer) and Urea fertilizer has been used, using the ratio 2:1.

- The first three numbers in the name of the fertilizer refer to the percentage of N, P_20_5 and K_2O respectively. This is a common way of naming NPK fertilizers (Clay et al., 2011).

- Urea consists for 46.6% of N, and does not contain P or K. The remaining 53.4% consists of carriers and fillers (Bareja, 2013).

- The basal dressing has been applied with a Fanta or Coca-Cola metal bottle cap, with lining removed. Lining is the plastic foil within the bottle top. Per planting station, the volume of two bottle tops has been applied, with the volume of one bottle top at either side of the plant. This was equal to 9 grams per planting station (Secretary for Agriculture and Food Security, 2012).

- o **Manure**

- The manure used had a composition of 11.6% N, 4% K_2O. As the N:P_2O_5 ratio for cattle manure is usually 2:1 and the P content was not known, the percentage of P_2O_5 was estimated to be 5.8% (Buckley & Makortoff, 2004).

- Per planting station, 200 grams of manure was applied. The manure was mixed with the soil around the planting station, just before planting.

Figure 10 One of the treatments

3. Top dressing

A top dressing is defined as the manure and/or fertilizer applied after the crop has started growing. It ideally provides N and other nutrients, which are needed later in the crop's growing cycle and also nutrients which, if applied earlier, would be easily lost from the soil before the plant could take them up (Baijukya et al., 2016).

Both a fertilizer top dressing and a manure top dressing have been used for the ARTs, both applied 21 days after planting:

- **Fertilizer**
  - The fertilizer has been applied 12.5 cm away from the planting station and 10 cm deep at either side of the plant.
  - The fertilizer top dressing comprised only of Urea.
  - The dressing has been applied with a Fanta or Coca-Cola bottle top, without lining removed. Per planting station, the volume of one bottle top has been applied, on either side of the planting station. This was again equal to 9 grams. Because of a difference in grain size between Urea and NPK, the lining did not have to be removed for the top dressing, in order to apply 4.5 grams per bottle top.
- **Manure**
  - The same manure has been used as described before. 200 grams of manure has been applied per planting station. The manure was mixed with the soil around the maize stand.

N, P and K are not always present in their pure form in the different inputs and outputs. However, all the nutrients are converted to weights of pure N, P and K. This has been done for the ease of compiling the flows and balances. This method has also been used in literature (Mehari Haile, 2007; Roy et al., 2003).

4. Alternative road option in floodplains: submergible roads

Nutrient balances have been compiled in order to research the sustainability of different nutrient management options. In the following sections, the inputs and outputs and their relevance for the different treatments are discussed. Table 2 and 6 show that not all possible inputs and outputs are relevant for all treatments.

Nutrient inputs

In table 2, a summary of this section can be found. A "V" in this table, means that this input has to be considered. A "0" in this table, means that this input can be neglected or is not applicable for N, P and K.

Table 2 Inputs to be considered

		Inputs to be considered				
Nr.	**Reference**	**Manures**	**Mineral fertilizers**	**Deposition**	**BNF**	**Sedimentation (floods)**
1	OO	V	0	0	V	V
2	FO	V	V	0	V	V
3	FP1	0	V	0	V	V
4	FP2	0	0	0	V	V
5	FR	0	V	0	V	V

Input 1: Organic Manures (OM)

This input has to be considered for treatment 1 and 2. In treatment 1, manure is applied as both a basal and top dressing. In treatment 2, manure is only applied as a basal dressing.

To transfer P_2O_5 to P, it has to be multiplied by 0.436. To transfer K_2O to K it has to be multiplied by 0.83 (Clay et al., 2011). This leads to the nutrient contents displayed in table 3.

Table 3 Manure composition

(g / kg)					
	N	P_2O_5	P	K_2O	K
Manure	116	58	25.29	42	34.86

Input 2: Mineral Fertilizers (MF)

Mineral fertilizers, referred to as fertilizers and inorganic fertilizers, are applied in treatment 2, 3 and 5. In treatment 2 and 3, fertilizer is applied as a top dressing. In treatment 5, fertilizer is both applied as a basal dressing and as a top dressing.

For the fertilizer basal dressing, a mix of NPK fertilizer and Urea has been used with the ratio of 2:1, as described in the methodology. The nutrient composition of Urea, NPK and this mix can be found in table 4.

Table 4 Mineral fertilizer composition

(g / kg)					
	N	P_2O_5	P	K_2O	K
NPK	230	100	43.6	50	41.5
Urea	466	0	0	0	0
Basal dressing	308.7	66.6	29.1	33.3	27.7

Input 3: Deposition (DP)

During the cropping season, there was very little rain. Besides that, no dust storms were recorded. For these reasons, atmospheric deposition of nutrients can be neglected for all the treatments.

This is also supported by formulas in literature. The most widely applied and reliable methods for determining the nutrient input through atmospheric deposition analyses depend on rainfall (Stoorvogel & Smaling, 1990).

Input 4: Biological N-fixation (BNF)

Biological N-fixation (BNF) is defined as the process in which nitrogen gas (N2) from the atmosphere is incorporated into the tissue of certain plants (Oregon State Univestiy, n.d.). Maize is not able to obtain N this way (Mehari Haile, 2007). The fields in this experiment have been and will be continuously (mono-)cropped with maize. This makes BNF hardly possible, and thus neglectable for all the treatments. However, via scattered trees, such as the acacia tree, BNF does take place. It is estimated that 2 kg N/hectare is brought in the system this way (Roy et al., 2003)

Input 5 : Sedimentation (SD)

Prior to planting, the field and surrounding areas have been flooded. This flood had a height of 2-3 meters and contained sediments. Within these sediments, nutrients were transported to the fields as well. Sediments that came with the 2 to 3-meter-high flood have partly settled on the field, including nutrients they contained. Part of the floodwater and sediments have flowed back to the Shire River. The specific quantity and quality of sediment settled is very time and place dependent, and furthermore differs per flood event. As it was impossible to exactly know the amount of sediments and its nutrient composition sedimented on the field, the assumptions in table 5 have been made, based on (Roy et al., 2003).

Table 5 Sedimentation (floods) composition

(kg / ha / year)					
	N	P_2O_5	P	K_2O	K
Sediment	10	3	1.3	5	4.2

Nutrient outputs

In table 6, a summary of this section can be found. A “V” in this table, means that this output has to be considered. A “0” in this table, means that this output can be neglected or is not applicable for N, P and K.

Table 6 Outputs to be considered

Nr.	Reference	Outputs to be considered: Crop residues	Harvested products	Leaching	Gaseous losses	Erosion
1	OO	V	V	V	V	0
2	FO	V	V	V	V	0
3	FP1	V	V	V	V	0
4	FP2	V	V	V	V	0
5	FR	V	V	V	V	0

Output 1: Crop Residue (CR) & Output 2: Harvested Products (HP)

These outputs have to be considered for all treatments. This has been done, based on the weight measured for the different harvested maize components. Different crops and part of crops withdraw different amounts of the various nutrients from the soil. A multiplication of the nutrient content, the yield and the area, leads to an amount of nutrients that come with the harvested crop (Roy et al., 2003). The nutrient concentrations in table 7 have been used as estimates (Hussaini et al., 2008).

Table 7 Grain and biomass composition of maize

(g / kg)	N	P	K
Grain	15.9	2.4	3.6
Biomass other than grain	0.47	0.22	1.53

Output 3: Leaching (LC)

Leaching is defined as the loss of water-soluble plant nutrients from the soil. Abundant rainfall and irrigation are the main factors affecting leaching (Li et al., 2008). There are multiple regression formulas that show leaching to correlate positively with rainfall and input 1 (organic manure) and input 2 (mineral fertilizer), and negatively with the total uptake of N and K (Roy et al., 2003).

The total uptake of N and K is the sum of the amount of N and K in crop residues (CR) and harvested products (HP). P is often bound tightly by soil particles and is hence assumed unsusceptible to any leaching process (Mehari Haile, 2007). As rainfall and irrigation were very low during the cropping season, they will be set to 0 in these formulas. The rainfall / irrigation parts can thus be left out of the formula. The set-up of these formulas and their values come from (Roy et al., 2003) and are suitable to use for SSA (Sub-Saharan Africa).

This leads to the formulas shown below.

Output 3 (N (kg/ha/year) = 2.3 + 0.3 (OM + MF) – 0.1 UN

OM = Organic manure (kg/ha/year)
MF = Mineral fertilizer (kg/ha/year)
UN = Total uptake of N (kg/ha/year)

Output 3 (K (kg/ha/year)) = 0.6 + 0.5 (OM + MF) – 0.1 UK

OM = Organic manure (kg/ha/year)
MF = Mineral fertilizer (kg/ha/year)
UK = Total uptake of K (kg/ha/year)

Leaching can thus only be calculated after calculating OM, MF, CR and HP. In case the formula calculated a negative outcome, this was interpreted as 0.

Output 4: Gaseous Losses (GL)

N is lost to the atmosphere by denitrification and volatilization. For SSA a formula has been made to calculate these gaseous losses (Roy et al., 2003). This formula takes into account the soil fertility, total application of fertilizer and manure, total uptake of N and the 'Base'. The 'Base' is a constant value, covering relative wetness of the soils specific for LWC (land / water class), and is 12 kg/ha/year for naturally flooded areas.

Output 4 (N (kg/ha/year)) = 'Base' + 2.5 x F + 0.3 x (OM + MF) – 0.1 x UN

F = Soil fertility class (1 = Low, 2 = Moderate, 3 = High)
OM = Organic manure (kg/ha/year)
MF = Mineral fertilizer (kg/ha/year)
UN = Total uptake of N (kg/ha/year)

For F, a value of 3 has been chosen, based on the relatively high fertility of wetland soils (Masija, 1991). As for leaching, gaseous losses can thus only be calculated after calculating OM, MF, CR and HP.

Output 5: Erosion (ER)

During the cropping season, almost no rain was recorded. Besides that, the slope of the field was close to 0%. For these reasons, erosion during the cropping season could be neglected. This was also supported by (Omuto & Vargas, 2019), who stated that the soil erodibility risk for the these dambos is low.

Yield

Per treatment, the on average produced grain and biomass per crop stand have been used to extrapolate to yield per hectares. In figure 11 the yield per hectare for the different treatments is shown.

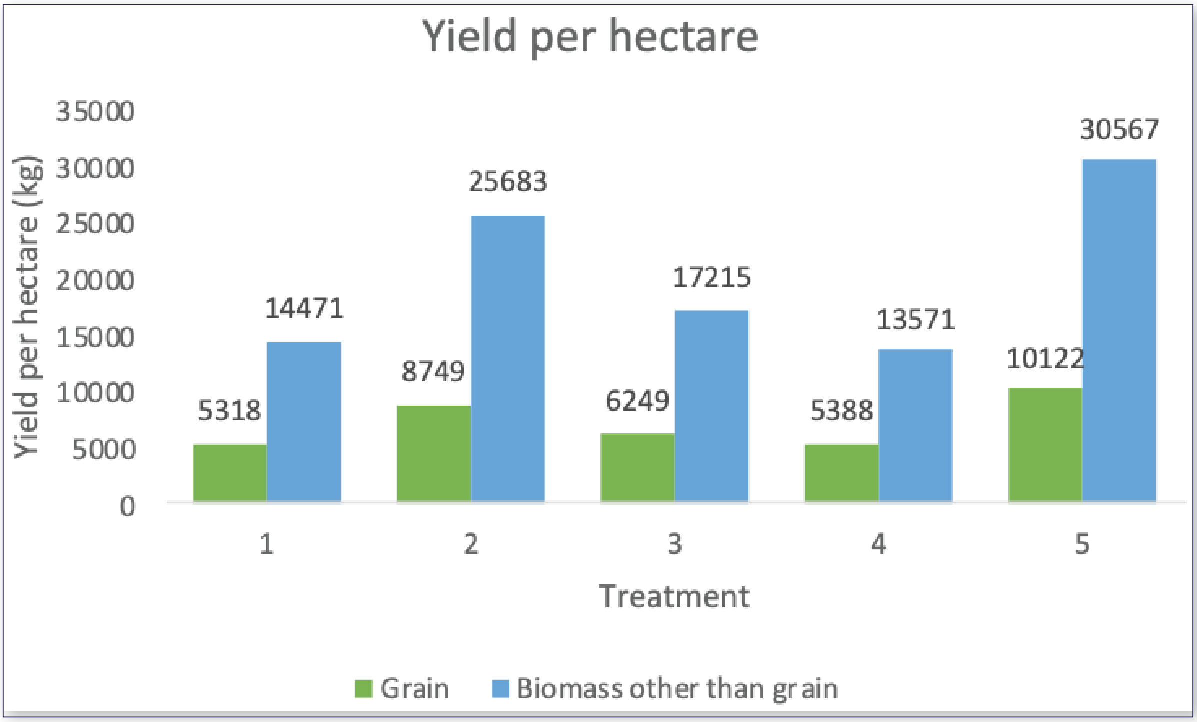


Figure 11 Yield per hectare

Figure 12 Measuring total biomass from a plot

Overview

For each input and output that had to be considered, the amounts of N, P and K that have been added or lost, are shown in the figures 13 and 14. All the amounts are displayed in kg/hectare and are calculated for the time span of one year. As explained, they are based on 53,333 crop stands per hectare.

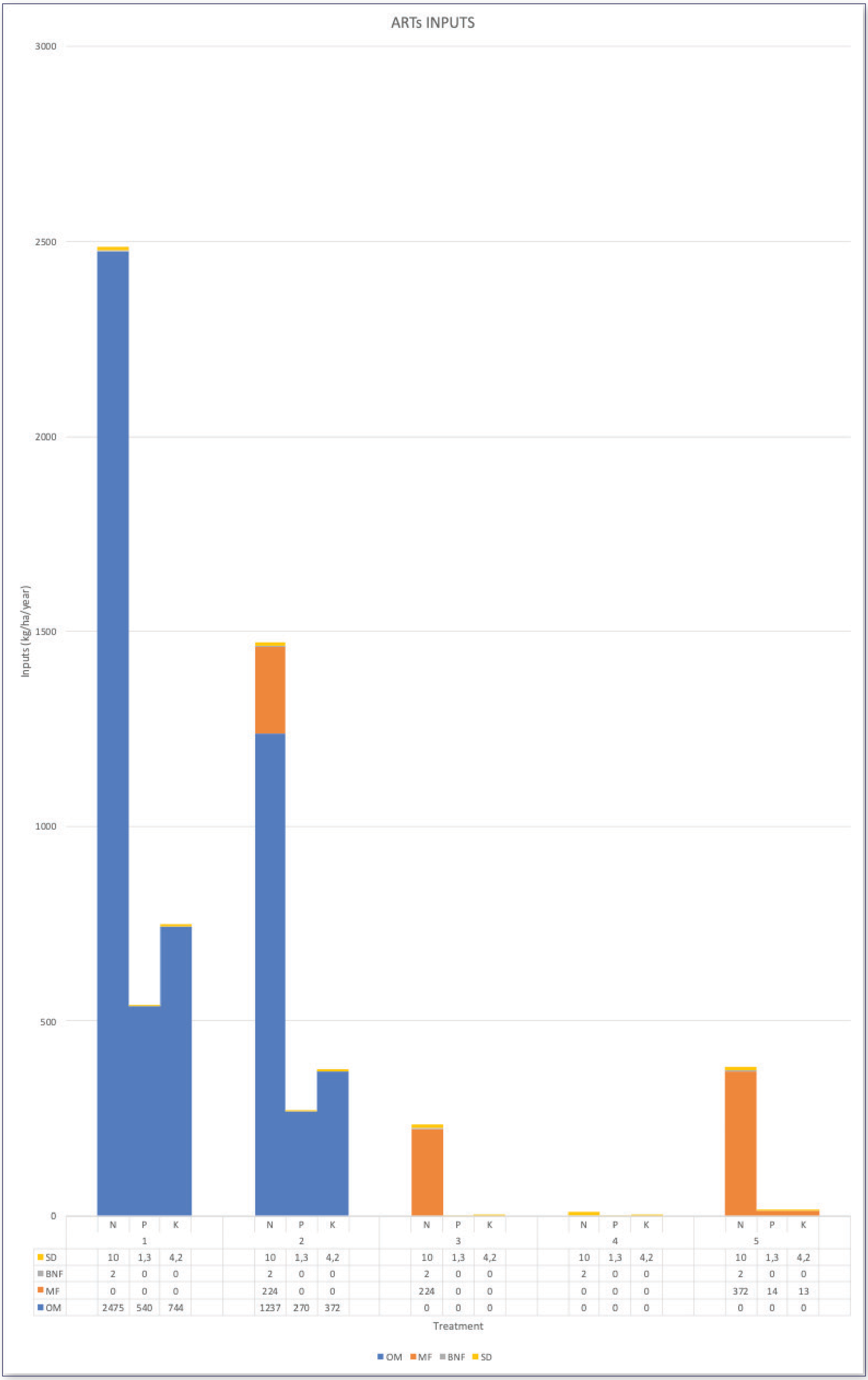
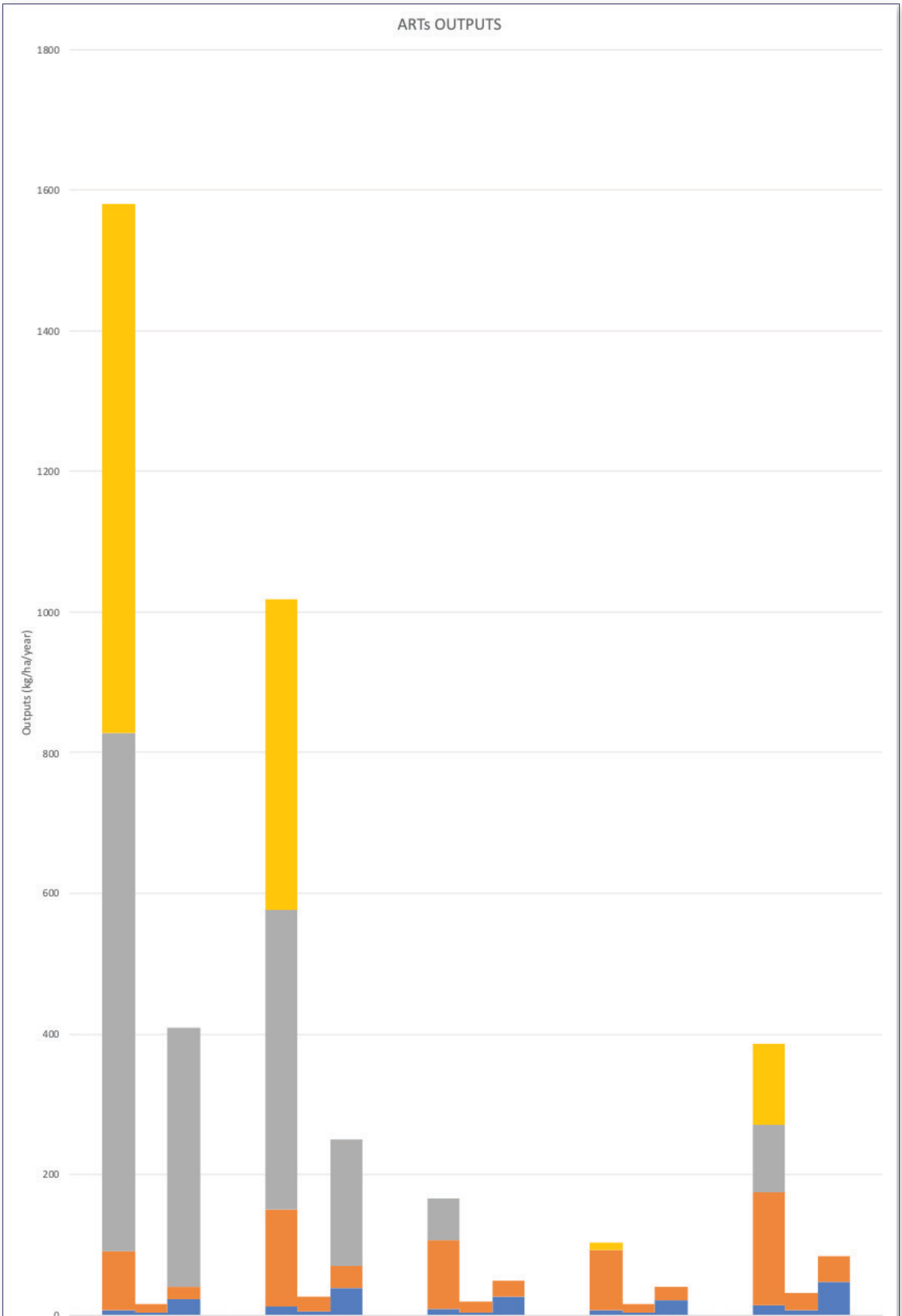


Figure 13 Inputs ARTs

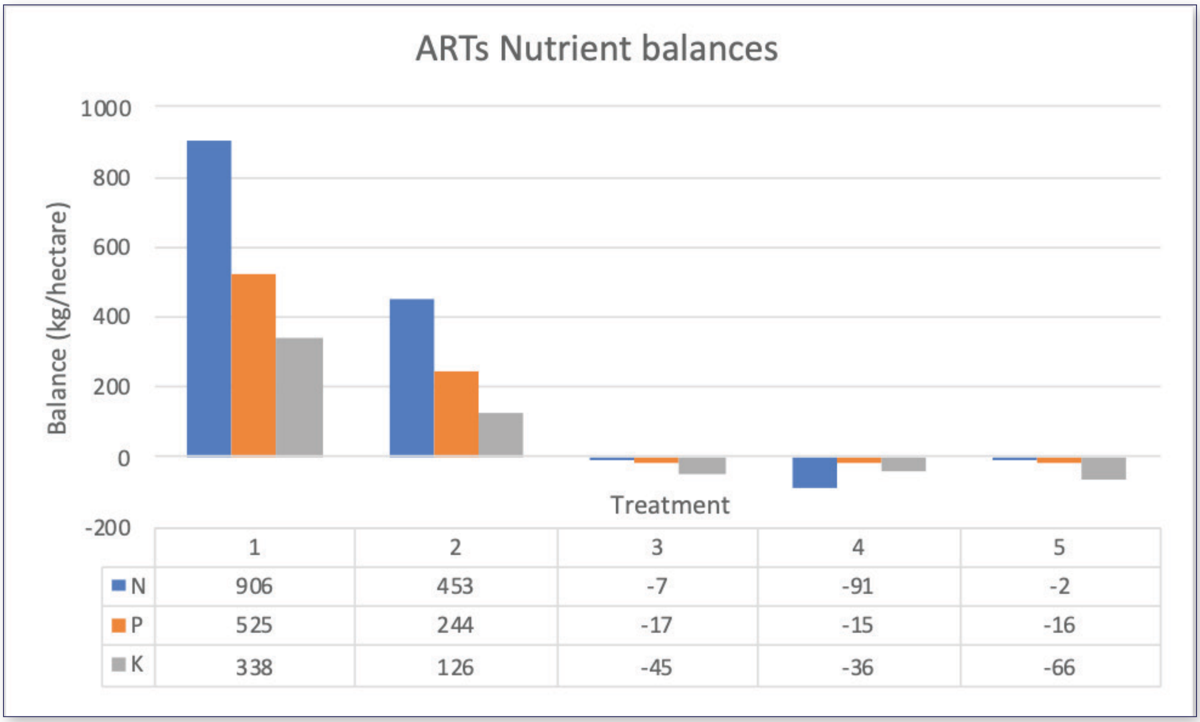


	1 N	1 P	1 K	2 N	2 P	2 K	3 N	3 P	3 K	4 N	4 P	4 K	5 N	5 P	5 K
GL	753,3	0,0	0,0	441,2	0,0	0,0	0,0	0,0	0,0	10,8	0,0	0,0	114,4	0,0	0,0
LC	735,6	0,0	368,3	425,5	0,0	179,4	58,7	0,0	0,0	0,0	0,0	0,0	96,3	0,0	0,0
HP	84,6	12,8	19,1	139,1	21,0	31,5	99,4	15,0	22,5	85,7	12,9	19,4	160,9	24,3	36,4
CR	6,8	3,2	22,1	12,1	5,7	39,3	8,1	3,8	26,3	6,4	3,0	20,8	14,4	6,7	46,8

Figure 14 Outputs ARTs

Nutrient balances

The nutrient balances, which are shown in figure 15, are the results of the sum of inputs and inputs. The interpretation of the inputs, outputs and balances can be found in the discussion and conclusion sections.



	1	2	3	4	5
N	906	453	-7	-91	-2
P	525	244	-17	-15	-16
K	338	126	-45	-36	-66

Figure 15 ARTs Nutrient balances

5. Discussion

Summary

The nutrient balances for treatment 3, 4 and 5 are all slightly negative for N, P and K. However, the yield in treatment 5 is almost twice the yield of treatment 3 or 4. This shows that increasing nutrient input via the recommended fertilizer regime does drastically increase yield. It also indicates that nutrients are the limiting factor in these trials.

The extra inputs of nutrients via organic manure, in treatment 1 and 2, lead to a lesser extent to increased yield but do ensure positive nutrient balances. The yield in treatment 1 was even slightly lower than the yield of treatment 4. This was not as expected and is probably caused by not-considered factors. The inputs for organic manure and mineral fertilizer were much higher than the inputs for BNF and sediments. For this reason, the exact values for BNF and sediment are less relevant for an indication of the nutrient balances. The relatively small inputs of nutrients via floods, suggested by literature, are in line with the low yields in treatment 3 and 4.

Outputs of nutrients can mainly be attributed to gaseous losses and leaching. The values for these factors were especially high for the treatments with organic manure and lower for the treatments with mineral fertilizers. For treatment 4, these factors were low or absent. The output of nutrients via harvested crop and crop residues varied and were higher for higher yields.

The positive nutrient balances in treatment 1 and 2 can be attributed to the organic manure. At first sight, it seems that overapplication of organic manure has taken place, as nutrient balances are very positive.

Different balances for N, P and K

The nutrient balances for N, P and K differ a lot. The N inputs via fertilizer and manure were higher than the P and K inputs via these flows. N outputs via gaseous losses and leaching were again higher than these flows for P and K, which were often even absent. For K, generally speaking inputs and outputs were lower than for N, and for P inputs and outputs were even lower.

Experiment conditions

In all treatments, the average yield was much higher than the normal yield of 2 to 3 ton per hectare. This can be explained by supplemental irrigation that is normally lacking and the laboratory-like circumstances. Furthermore, excellent care has been taken over weed control and application of fertilizer and/or manure which have all benefited yields, which is not likely to be applied in the normal field conditions, outside the trial set-up. These results show that enormous yield increases are possible but implementing these to the farmers' own fields is challenging. This might have been frustrating for farmers, who have participated in these ARTs in order to implement measures on their own field after seeing their successes. The main bottlenecks are the lack of inputs and lower degree of management in farmers' own fields.

Soil

In table 8, the average values for soil nutrient depletion in Malawi are shown. These values are within the range of the results of the different treatments (figure 14). The balances for treatment 4 are even close to these values. This indicated that treatment 4 is comparable with the national average. Less negative or more positive nutrient balances under treatment 4 were expected, since the wetlands have the advantage of nutrients coming in via floods. Many other parts in Malawi, on which table 8 is based, do not have this input. A counter argument is that in other parts of Malawi fertilizer is almost always used.

Table 8 Average nutrient balance Malawi in 2000 (Roy et al., 2003)

(kg / ha / year)			
	N	P	K
Balance	-67	-10	-48

Crop residues and animals

Within this research, crop residues were seen as an output of the system. In reality, the crop residues are fed to the animals, which are also allowed to graze the fields after harvesting. The nutrient flow from livestock directly to the field is not considered, as no data on this flow was available. The effect of animals on the nutrient balance could be both positive or negative, depending on the amount of nutrients dropped via manure and the amount of nutrients extracted from the fields via grass, weeds and stubbles.

Positive nutrient balances

Under treatment 1 and 2, positive nutrient balances have been calculated. The risk of pollution was however low, since the soils in the ARTs have been overexploited in the past years. These positive balances will thus mainly improve the soil fertility without polluting the environment.

Scalability

One of the goals of the ARTs was to change the practices of farmers on their own fields, in order to increase their yields. Due to limited availability of manure, fertilizer and supplemental irrigation water, the application of the recommended fertilizer regime remains probably limited. Furthermore, taking excellent care of crops is much more challenging in larger fields. The calculated yields for the ARTs are very promising but are not realistic for normal fields situations. However, some of the mentioned challenges can be overcome, ensuring an increase in yield for farmers and a more fertile soil. In the recommendations section, scalability is mentioned once again.

6. Conclusion

It can be concluded that nutrient balances are negative under current practices. Increasing nutrient input did result in higher yields but did not always result in more positive nutrient balances, and thus in the sustainability of the farming system.

Increasing inputs via organic manure did lead to positive nutrient balances, but to a limited extent to increased yields. Increasing inputs via the recommended fertilizer regime, did ensure a massive increase in yield but did not ensure a positive nutrient balance. As not all flows have been measured, some had to be estimated based on expert knowledge and literature. For these reasons, the results should be viewed as an indication of the reality.

The calculated positive nutrient balances are not by definition positive for the farming system. However, in the wetlands of the Chikwawa district, they are positive since the soil fertility has declined a lot and the positive balances will improve the soil fertility.

A last conclusion is about the sediments the floods in flood recession agriculture bring. These sediments are often seen as a major source of nutrients but are only of limited importance as stated in the results of this research. The sediments, and specifically the clay particles, are beneficial for soil structure and potential soil fertility. However, in order to make optimal use of these sediments, inputs of nutrients via organic manure and/or mineral fertilizers are required.

Figure 16 Farmers who participated in the ARTs

7. Recommendations

With regard to the ARTs, some changes and additions to the experiment would improve the accuracy of the compiled nutrient balances. The following recommendations are made for the ARTs:

- Using larger plots would make the compiled nutrient balances more reliable, as the influence of outliers on the average will then decrease.
- A more elaborate analysis on the nutrient content of the manure would improve the reliability of the results. Then the P content would be known and does not have to be estimated.
- More research on the sediments that are brought by the flood should take place. The use of sediment pins in combination with analysis of the sediments, enables one to better estimate input of nutrients via sediments (Mehari Haile et al., 2011).
- An analysis of the nutrient composition of harvested products and crop residues would improve the reliability of the research, as these values were now retrieved from literature.
- More elaborate soil sampling, in order to verify the calculated balances.
- A follow-up of the ARTs could be organised after the next growing season(s), in order to test the scalability and to discuss further improvements.

It is also recommended to further expand the scope of the ARTs with the inclusion of other recommended practices, for example discussed in (van Steenbergen et al., 2010). This would result in more treatments. Combinations of different manure / fertilizer application and some of the treatments could results in interesting outcomes. Potentially, some of these practices and increase fertilizer/ manure will benefit from each other.

The research topics listed below are out of the scope of this note and the associated thesis, but very interesting and relevant to dive into.

- Availability, costs and profitability of fertilizer and manure.
- Nutrient composition of sediments in floodwater in general.
- Research on nutrient balances in different FBLS.
- Comparison of nutrient balances in flood recession agriculture with other nutrient balances in Malawi.
- Comparison of nutrient balances in FBLS and rainfed/irrigated agriculture in general.
- Research on losses via leaching and gaseous losses in flooded areas.

This research forms one of the starting points in exploring the exceptional possibilities FBLS offer!

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Practical Note #39

Colophon

This Practical Note was prepared by David Mornout. It is mainly based on his BSc Thesis which has been written during his internship at MetaMeta in Wageningen.

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A short clip with a presentation about the thesis can be accessed via The Water Channel: www.thewaterchannel.tv/videos/nutrient-balances-in-flood-recession-agriculture-malawi/

Flood-Based Livelihoods Network Foundation

Flood-Based Livelihoods Network Malawi

Rainwater Harvesting Association of Malawi
Making sure every drop counts

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The Flood-Based Livelihoods Network (FBLN) supports and promotes appropriate programmes and policies to improve flood-based livelihoods systems (FBLS) through a range of interventions, assists in educational development and knowledge-sharing, creates networks and supports the implementation of projects on FBLS. For more information: www.spate-irrigation.org and www.fblnmalawi.org

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